The Journal of

The Institution of Engineers

(India)

Vol-20

1941

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THE JOURNAL
OF
The Institution of Engineers (India).
INCORPORATING THE TRANSACTIONS OF THE LOCAL CENTRES

Edited and Published for the Institution
by the Secretary, Rai C. C Seal Bahadur 124 447

Vol. XX JANUARY 1941

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Khan Bahadur M. Abdul Aziz, C.I.E., M.I.E. (Ind.)

PRESIDENT 1939-40.

The Institution of Engineers (India).

Minutes of proceedings of the Twentieth Annual General Meeting held at Hailey Hall, Lahore, on Friday, the 12th January 1940, at 11 A.M.

PRESENT.

Mr. E. J. B. Greenwood (in the Chair).

Khan Bahadur M. Abdul Aziz, C.I.E. (later in the Chair).

Rai Bahadur B. P. Varma.

Rai Bahadur Chuttan Lal.

Mr. Fakirjee E. Bharucha.

Mr. B. S. Chetti.

Mr. S. N. Ghose.

Mr. M. C. Gupta.

Mr. Dildar Hosain.

Rao Saheb N. S. Joshi.

Mr. S. B. Joshi.

Mr. B. R. Kagal.

Mr. Mohsin Ali.

Dewan Bahadur A. N. Nanda.

Sardar Bahadur Prabh Singh.

Mr. Siri Ram.

With 43 Corporate Members, 1 Associate and 3 Students.

Rai C. C. Seal Bahadur (Secretary).

PROCEEDINGS.

1. Khan Bahadur A. G. Khan proposed that the Minutes of the Nineteenth Annual General Meeting, copies of which had been circulated previously, be taken as read and confirmed.

Mr. Fakirjee E. Bharucha having seconded, the proposal was put to vote and was carried unanimously.

2. In presenting the Annual Report and the audited accounts for the year ending 31st August 1939, Mr. E. J. B. Greenwood, the retiring President, said :—

"Gentlemen,

Our next business is to have the Annual Report of the Council for the year ending 31st August 1939 adopted and the audited accounts passed. That report with the accounts have already been posted to every member and will be taken as read. Before calling on Rai Bahadur Varma to propose their adoption and the subsequent invitation to members to comment thereon I would like for their information to mention the progress made on the more outstanding items of the report since its closing date 31st August.

In the matter of the Technical Secretary the sub-committee of five including myself has short-leeted three of the 76 candidates and your Council at its meeting tomorrow will proceed with the final choice ; I expect he will be able to commence his duties from the first of March. With his appointment a great advance will be possible in our activities and development.

As regards the Registration of Engineers in India the majority of our members in Bengal and Bombay is in favour of legislation. The matter is a very far-reaching one and although the draft Bill is necessarily incomplete and particularly so over the vexed question of minimum qualifications it was referred in November to all Local Centres for remarks. I strongly endorse the appreciative remarks of the Council over this Sub-Committee's clear and judicious report. Members may have noticed with interest that in the U.S.A. the Institute of Electrical Engineers has approved a draft model Law for the Registration of Engineers ; it follows broadly our own draft bill and may be found in "*The Electrical Review*" for 29-9-39. Great Britain

has moved towards the same end but in a lesser degree in the formation of a non-statutory Engineers' Guild. Subsequent action in both countries will no doubt be watched with keen interest.

As regards our examinations, their syllabii and their recognition not only by governments in India but by the principal engineering Institutions of Great Britain, members will I am sure view with warm appreciation the solid advances made during this year. This work of improving our examination to suit the rising standard of engineering development goes on continuously year by year and is never finished; the portals of our Institution are jealously guarded.

I would take this opportunity to record my great admiration of the co-operation and able work of very many of our Members of Council; our Institution owes a debt of gratitude to all those members who have given it so ungrudgingly their time and abilities; more personally I would mention with appreciation the work of our Secretary Rai C. C. Seal Bahadur and the office under him; I consider his able control of our accounts is of outstanding merit.

With these remarks I would call on Rai Bahadur Varma to propose the adoption of the Report and Accounts."

Rai Bahadur B. P. Varma proposed that the Annual Report be adopted and the accounts passed.

Khan Bahadur A. G. Khan seconded.

RESOLVED that Annual Report be adopted and the accounts passed.

3. The Chairman said that under Bye-law 57, Auditors were to be appointed at the Annual General Meeting to hold office until the next Annual General Meeting and that he had therefore taken up this item although it was not mentioned in the agenda. He asked some member to make a motion in that regard.

Mr. J. Ganguly proposed that Messrs. Price, Waterhouse, Peat & Co., be re-appointed Auditors for the ensuing year on the same remuneration *viz.* Rs. 350/- per annum.

Mr. S. N. Ghose seconded.

Mr. H. F. Bamji said that it had been suggested at the Annual General Meeting held at Hyderabad that the Auditors should be changed. He asked what action had been taken.

The Chairman asked the Secretary to reply.

The Secretay said that, as far as he remembered, the matter was left to the discretion of the Council and when it came up again at the Annual General Meeting last year, the same firm was appointed.

Mr. B. R. Kagal enquired whether it was not open to the meeting to suggest another name.

The Chairman replied in the affirmative and asked the members whether they had any other names to suggest. As no other name was suggested, it was resolved that Messrs. Price, Waterhouse, Peat & Co., be re-appointed Auditors for the ensuing year on the same remuneration, *viz.* Rs. 350/- per annum.

4. The Chairman announced that under Bye-law 18 the following Members had been elected by the Local Centres to fill the vacancies on the Council :—

Mr. B. N. Mookerjee ..	Bengal Centre.
Mr. L. P. Misra. ..	,, ,,
Col. C. Warren-Boulton ..	,, ,,
Mr. W. Gow. ..	,, ,,
Mr. J. D. Daruvala ..	Bombay Centre.
Mr. E. A. Nadirshah ..	,, ,,
Rao Saheb S. N. Joshi ..	,, ,,
Mr. T. R. S. Kynnersley ..	,, ,,
Sardard Bahadur Prabh Singh ..	N. W. I. Centre.
Mr. Sri Ram ..	,, ,,
Dewan Bahadur Amar Nath Nanda	,, ,,
Mr. B. R. Kagal ..	,, ,,
Mr. M. C. Gupta ..	U. P. Centre.
Mr. H. G. Trivedi ..	,, ,,
Mr. Dildar Hosain ..	Hyderabad Centre.

5. The Chairman announced that under Clause 6 (b) of the Charter the following Chairmen of the Local Centres noted against each would become *ex-officio* Vice-Presidents of the Council :—

Mr. S. C. Majumdar	..	Bengal.
Mr. J. D. Daruvala	..	Bombay.
Rao Bahadur C. V. Krishnaswamy Chetty, M.B.E.	..	South India.
Mr. B. R. Gurudachar	..	Mysore.
Mr. Mahabir Prasad	..	United Provinces.
Mr. Hasan Latif	..	Hyderabad.

He added that the North West India Centre had not elected their Chairman, but would do so at a later date.

He also announced that the following past Presidents would become *ex-officio* Members of Council :—

Col. F. C. Temple, C.I.E.
Rai Bahadur Chhuttan Lal.
Mr. Fakirjee E. Bharucha.
Mr. E. J. B. Greenwood.

6. In welcoming the new President, Khan Bahadur M. Abdul Aziz, C.I.E., the retiring President (Mr. E. J. B. Greenwood) delivered the following speech :—

"I have now great pleasure in introducing our new President Khan Bahadur M. Abdul Aziz. Born, I think, in 1884 he was educated at the M.A.O. College, Aligarh (now the Muslim University) and at the Thomason College, Roorkee ; he was appointed to the Indian Service of Engineers in 1909 and promoted to Executive Engineer in 1920 ; in 1928 he became Under Secretary to Government of the United Provinces and in 1931 he was promoted to Superintending Engineer. He took a prominent part in the construction of the Ganges Canal Hydro-Electric works and the Tube-well projects and in the due course was honoured with a C.I.E. by a grateful King-Emperor. He became Chief Engineer, Irrigation Branch, U.P., in 1936 and just one month ago retired after a conspicuously able career.

He joined the Institution in 1922 as an Associate Member and became a full Member in 1932 ; he has been for years a

prominent Member of our Institution and on none else could the mantle of President be more deservedly bestowed. I have the greatest pleasure therefore in calling on Khan Bahadur Abdul Aziz, C.I.E. to assume the office of President of the Institution of Engineers (India) and to address the gathering."

Khan Bahadur M. Abdul Aziz, C.I.E., then took the Chair amid cheers and delivered his Presidential Address.

7. The question as to whether the Institution should give a prize from its own fund to Mr. T. R. S. Kynnersley and Rao Saheb N. S. Joshi for their papers entitled, "Concrete Roads and the Bullock Cart" and "Lacey's Theory and Deccan Canals" respectively was considered.

RESOLVED that the Council be informed that the general body was not in favour of awarding cash prizes for meritorious papers and was of the opinion that the Council should show their appreciation of the meritorious papers submitted by the two Members in some other form.

8. Item 8 of the main agenda and item 13 of the supplementary agenda regarding the Bill for Registration of Engineers in India were considered together.

RESOLVED that in view of the fact that the report of the Sub-Committee appointed to go into the Bill, was already under consideration of the Council, no action was called for.

9. In moving the following resolution Mr. S. B. Joshi said that he was ashamed that he was unable to help the Allies with anything more than by giving money :—

> The General Meeting of the Institution of Engineers (India) resolves that in the prosecution of the present War the co-operation of Engineers in India in every possible way should be made available to His Majesty's Government and confirms the assurances of full co-operation already conveyed by the President to the Government of India, on behalf of the Institution.

Rao Saheb N. S. Joshi supported.

After some discussion the resolution was put to vote and was carried by a majority.

10. The following resolution moved by Mr. S. B. Joshi was put to vote and was rejected by a majority :—

The General Meeting of the Institution of Engineers (India) resolves that with immediate effect the Institution should begin to collect a substantial fund, the amount of which should be decided by the Council, for contribution towards the prosecution of this War.

The meeting was of the opinion, that it was not necessary to open a separate fund, but the Members should support the separate local and all-India funds already started.

11. The following resolutions moved by Mr. S. B. Joshi were put to vote and were carried by a majority :—

(a) The General Meeting of the Institution of Engineers (India) resolves that the Government of India should also be advised that, for the security of India and the Commonwealth of which it is a part, it is necessary that Government take immediate steps to train every Engineer in India in the science and practice of modern mechanised warfare, so as to enable him to do his duty to the Crown, much more effectively than has hitherto been possible.

(b) The General Meeting of the Institution of Engineers (India) resolves that the Government of India be requested to give full co-operation and financial assistance to this Institution for investigating the possibility of manufacturing armaments of all kinds in India under the control and management of Indian Engineers.

12. Mr. S. B. Joshi moved the following resolution :—

The General Meeting of the Institution of Engineers (India) resolves that it is not in the interests of the Institution to allow a feeling to grow that Members of Council from one province only control the affairs of the Institution and that in the government and control of the Institution and its affairs greater collaboration than what exists to-day between Members of Council from all parts of India is desirable.

That with this end in view the places of Meetings of Council should be as shown below:

(1) First meeting at the place where the Annual Session is to be held.

(2) Three meetings at the Headquarters of the Local Centre to which the President belongs.

(3) Three meetings at Calcutta.

(4) Three meetings at Bombay.

(5) Two in the jurisdiction of some of the other local centres, at the discretion of the President or at the Headquarters.

Mr. J. Ganguly said on a point of order that according to para 9 of the Charter the business of the Council should be conducted in such a manner as the Council might from time to time prescribe. The question as to the place where Council Meetings were to be held should be left to the discretion of the Council.

Mr. S. B. Joshi pointed out that according to Bye-law 58, in the government and control of the Institution and its affairs the Council was subject to such regulations as might be prescribed by the Institution in General Meeting and in holding the Council Meetings at different places the general body was making the Council's work truly representative in character and was as such giving effect to the spirit and the letter of the Charter.

The Chairman ruled that the motion was in order.

In opposing the motion Mr. S. N. Ghose said that there would be many difficulties in conducting the business of the meetings if the meetings were not held at the Headquarters of the Institution. He added that if it was really necessary to leave the question of fixing the place of Council Meetings to the discretion of the President, he should be authorized to fix the place of all the eleven meetings, the first meeting being held along with the Annual General Meeting as usual.

In seconding Mr. S. B. Joshi's proposal Mr. E. J. B. Greenwood suggested the following amendment. *viz*. the first meeting be held at the place where the Annual General Meeting is held, three meetings at Calcutta, three meetings at Bombay, and the rest of the meetings at the discretion of the President.

Mr. S. B. Joshi agreed to the amendment proposed by Mr. Greenwood.

The resolution as amended by Mr. Greenwood was then put to vote and was carried by a majority.

13. Mr. S. B. Joshi moved the following resolutions :—

(a) This meeting suggests that the Council do consider the advisability of appointing one of the Council Members, as an Honorary Secretary, for assisting the two secretaries of the Institution.

(b) The General Meeting of the Institution resolves that the Council do frame a scheme for the establishment of the "Indian Standardization Board" and approach the Government of India for its immediate adoption.

(c) This meeting resolves that the report of the Sub-Committee appointed by the Council for considering the draft act for Registration of Engineers be circulated to all members for expressing their opinion on the same.

It was resolved at the suggestion of Mr. S. B. Joshi that these matters be referred to the Council for consideration.

14. The resolution regarding the professional conduct rules and scale of fees which Mr. J. Ganguly proposed to move, *vide* item 10(1) of the supplementary agenda, was withdrawn as he was given to understand that these matters were already under consideration of the Council.

Meeting adjourned till 2-45 p.m. the same afternoon.

Minutes of the adjourned Annual General Meeting of the Institution of Engineers (India) held at the Hailey Hall, Lahore, on the 12th January, 1940, at 2-45 P.M.

PRESENT :

Khan Bahadur M. Abdul Aziz, C.I.E., (in the Chair).

Rai Bahadur B. P. Varma.

Rai Bahadur Chhuttan Lal.

Mr. Fakirjee E. Bharucha.

Mr. E. J. B. Greenwood.

Mr. B. S. Chetti.

Mr. S. N. Ghose.

Mr. M. C. Gupta.

Mr. Dildar Hosain.

Rao Saheb N. S. Joshi.

Mr. S. B. Joshi.

Mr. B. R. Kagal.

Mr. Mohsin Ali.

Dewan Bahadur A. N. Nanda.

Sardar Bahadur Prabh Singh.

Mr. Siri Ram.

With 31 Corporate Members.

Rai C. C. Seal Bahadur (Secretary).

15. Mr. J. Ganguly moved the following modified resolution in place of what was printed on the supplementary agenda as item 10 (2) :—

This Institution urges on the necessity of the Institution to inviting the Indian Road Congress and similar bodies to join this Institution and also the necessity of starting specialized sections of its own in order to take up the work of these bodies.

In moving the modified Resolution Mr. J. Ganguly said that the Chief Engineers, Superintending Engineers and Executive Engineers of Public Works Departments of all the provinces who had, from the inception of the Institution, taken active part in the Institution have practically all left our Institution leaving the juniors (Assistant Engineers) to stick to membership for better prospect in their service than those who had still not joined. The inaugural speech which had been printed in the Agenda clearly showed that this Institution was best fitted to do the specialised work. But the recent formation and the support of the senior members of the P. W. D. had fostered up the Congress to its present healthy condition. Papers are read by members of this Institution at the meetings of the Congress while the dearth of papers written from practical point of view is keenly felt by us.

Mr. M. N. Mukerji seconded the resolution.

Mr. Mohsin Ali said that the proposed resolution would not bear fruit as in his opinion it was impossible to ask well-established Institutions like the Indian Road Congress and the Punjab Engineering Congress to commit *hara-kiri* for the benefit of the Institution of Engineers (India). He added that the Institution of Engineers (India) was not a provincial body but embraced the whole of India in its sphere and the members ought to welcome all engineering progress, research and advancement whether it was done within or outside the Institution.

Rai Bahadur Chhuttan Lal remarked that Mr. Ganguly had said that this Institution should take over the work of the Indian Road Congress and other similar bodies. So far as the Indian Road Congress was concerned, it was impossible for this Institution to do the work of the Congress. The Congress had the entire strength of British India and the States behind it. They spent large sums of money on research and had a large staff. The main object of the Congress was to pool the experience and exchange of ideas for the construction and maintenance of roads in India. It was a semi-official body and managed by a committee consisting of Chief Engineers of Provincial Governments, Road Engineers, etc. So far as the starting of specialized sections was concerned, the Institution was not in a position to carry out the work of the Indian Road Congress.

Mr. J. Ganguly replied that the Institution of Engineers (India) had nearly 1,500 members. The Institutions of Civil, Mechanical and Electrical Engineers in London had more than 10,000 members. So if the work done by the Indian Road Congress were taken over, it would never be unwieldy. He was astonished to find that the Institution had forgotten so soon the objects for which it had been founded. He was of the opinion that the members of the Indian Road Congress should join this Institution.

The following amended resolution proposed by Mr. Mohsin Ali was then put to vote and was carried by a majority :—

This Institution should start specialized sections in different branches of Engineering and invite collaboration from other professional bodies like the Indian Road Congress, the Central Board of Irrigation and the Punjab Engineering Congress in the best interests of the Engineering profession.

16. The following resolutions were moved by Rao Saheb N. S. Joshi :—

(a) With a view to making the Committees of Local Centres, truly representative of the corporate members in their respective jurisdictions—this meeting resolves that the elections of the Local Committees be held by postal ballot.

(b) This meeting recommends that the Members of Council from a local centre should be invited to attend all the meetings of the committee of that local centre, for the purpose of deliberations and mutual consultation. This will be useful in keeping the local committee in touch with the activities of the whole Council. Members of Council attending such committee meetings should not have a vote unless they are themselves members of the committee.

With regard to (a) Mr. J. Ganguly pointed out that this could not be done at the Annual General Meeting as it involved a change of the Bye-laws.

The resolutions were put to vote and were carried by a majority.

17. The resolution regarding holding of Council Meetings at some central place proposed to be moved by Rao Saheb N. S. Joshi was withdrawn.

18. Rao Saheb N. S. Joshi moved the following resolution :—

This meeting resolves that a compulsory subject of Mathematics (including Calculus, Trigonometry, Co-ordinate and Solid Geometry and Statistics) should be added to the subjects for examination in Section A.

RESOLVED that the matter be referred to the Council for consideration.

19. Mr. H. F. Bamji moved the following resolutions :—

(a) That while filling up vacancies in the Council and in the election of members of local committees, special regard to the proper representation of all engineering interests (civil, electrical and mechanical) be made so that members of all branches of the engineering profession are duly represented.

(b) That a member elected for the Council automatically ceases to be an ordinary member of the local committee. (The above to be added to Bye-law No. 18).

He prefaced these resolutions with the following speech :—

Mr. President and Brother Engineers,

The resolutions that are standing in my name and which I get up to move with the support of about 75 members are intended to bring about changes in the formation of the Council and of the local Committees. In the formation of the Council and the local Committese there has been of late a tendency to overlook the spirit of our constitution in not providing adequate representation of all branches of the engineering profession. Gentlemen, you are aware that this Institution was founded by eminent engineers of standing in Electrical and Mechanical engineering with the help of Civil Engineers. The tradition that they set up of having the co-operation and representation of all engineering professions in India should be continued to ensure the growth and strength of the Institution.

In the initial Council of the Institution as per Article 32, out of 19 names of prominent engineers, 11 belonged to the Electrical and Mechanical branches of the profession. From this it will be clear to you that the promoters of the Institution had clearly in mind that proper representation on the Council should be given to all branches of Engineering, Electrical, Mechanical and Civil. Also in bye-law No. 53 it is clearly stated that, in filling up casual vacancies, the Council shall have special regard to the proper representation of engineering interests and of all areas to which the activities of the Institution extend. It is true that in bye-law No. 18 regarding the representation of Local Centres in the Council specific reference is not made for representation of all branches of Engineering. This is only a chance omission as it was understood that in electing representatives from the Local Centres due regard would be given to the representation of all interests. The last sentence of Article 3(b) of the Memorandum of Association is specially significant in this connection and it reads as follows :—

> "The object of the association shall be to assure to each individual member as far as may be possible to enjoy the equal rights and privileges of the association."

This cannot be realised unless members who hail from all the different branches of the profession are given adequate representation in the Council and the Local Committees including 770 Associate Members, when the expenses of the local centres alone is about Rs. 15 to 17 per Corporate Member.

Out of about 45 Members of the Council from Local Centres, there are 2 members representing the Electrical branch from South India including the President ; 3 members representing Mechanical and Electrical Engineering from Bengal ; and 2 members representing Mechanical Engineering from Bombay Centre including the immediate past President, Ex-officio Members of the Council; in all 7 Members including 3 Ex-officio and 4 elected, representing both Electrical and Mechanical Engineering branches. The remaining about 38 are mostly representatives of Civil Engineering. This shows that representation on the Council of Electrical and Mechanical Engineers is not sufficient and is likely to go down if adequate measures are not taken by the members concerned to remedy this state of affairs. For a good number of years there has been no

representative of the Electrical Engineering branch from the Bombay Centre on the Council of the Institution inspite of there being on the roll of members of the Bombay Centre, engineers holding very responsible positions in Hydro-electric cencerns, electrical branch of the railways, tramways and factories specially interested in Electrical Engineering.

At present for the 10 elected seats on the council from the Bombay Centre, there are 9 Civil Engineers and one Mechanical and Electrical Engineer. It is possible that, if things continue like this, at the next election all the 10 members will be from the Civil Engineering branch only. Yet in an important engineering centre like Bombay, the engineering activities are predominantly of electrical and mechanical groups. The question then naturally arises as to how to remedy this state of affairs. If adequate provision is made for the representation of all the branches of the engineering profession on the Council and the Committees, I feel certain that papers and discussions on subjects relating to all branches of engineering will come forward and the activities of the Institution will in general become truly representative of the different engineering interests in the country which was the aim and object of the original promoters.

The second part of the resolution is intended to remedy certain practices which are gaining ground in the annals of the formation of the Local Committees. At present Members of the Council are on the Committees of the Local Centres., If the second part of my resolution is given effect to, it will widen the scope of representation to the Council and to Committees to a larger circle of enthusiastic Members and 770 Associate Members who are now found to be on the waiting list. Some of them are very enthusiastic about taking up any kind of honorary work to promote the cause of Engineering in India and they are denied the privileges of doing such work on account of the Members of the Council monopolising seats on the Local Committees. In the Institution there are about 45 Council Members, 80 Local Committee Members of India, and 62 on the Committees of the Council, in all 187 seats represented by about 90 Corporate Members with a very negligible proportion of Associate Members inspite of their being in an overwhelming majority. Taking

the case of Bombay Centre, there are 11 representatives on the Council from the Local Centre and 12 on the Local Committee and 9 on other Sub-committees of the Council, in all 32 representatives which are monopolised by 15 members of the Centre. If the second part of my resolution is given effect to, it will give representation to 32 members and not to 15 members as at present.

The Secretary submitted the following papers :—

(a) Joint letter dt. 20-12-39 signed by 20 Members including Mr. H. F. Bamji asking for inclusion of the above resolution in the agenda for the Annual General Meeting.

(b) Telegram from Mr. A. K. Modi, dt. 11-1-40.

(c) Letter dt. 5-1-40 from Mr. W. B. Burford.

(d) 55 letters from various Members supporting the resolution.

In supporting the resolutions proposed by Mr. H. F. Bamji regarding the want of adequate representation of all branches of engineering profession such as Mechanical, Electrical, etc., besides Civil engineering, Mr. Fakirjee E. Bharucha said that he knew that it was not possible to amend the Bye-laws without referring the matter to the Privy Council. But the Council could draw the attention of the members and request them to bear in mind the suggestion for the adequate representation on Council of various engineering lines when votes electing members on Council were invited.

Regarding the second part of the Resolution in which Mr. Bamji had proposed that a Member of Council should not offer himself to be re-elected after remaining on the Council for a certain number of years, Mr. Bharucha also concurred with his view saying that if the Members of Council remained as such for a long time, it deprived other members from giving their services. The period a member should work on Council should therefore be restricted so that the others, who were anxious to serve on the Council, might get an opportunity to do it.

Rao Saheb N. S. Joshi wanted to know whether the existing elected members on the Council were in proportion to the total number of Members and Associate Members of the Institution under the three heads, Civil, Mechanical and Electrical.

Mr. S. B. Joshi observed that if Mr. Bamji's idea was to fill casual vacancies in the Council with due regard to the representation of all engineering interests, Bye-law 53 provided for that and Mr. Bamji's resolution only confirmed what the Bye-laws had already provided. If, however, Mr. Bamji wanted that the annual elections to the Council should be held in such a way as to give weightage or reservation to some particular engineering interests, such as Mechanical and Electrical Engineering, such a resolution could not be considered at the Lahore Meeting as it involved a change in Bye-laws. Mr. Joshi, therefore, was of the opinion that Mr. Bamji instead of allowing both his resolutions to be declared *ultra vires*, should accept a suggestion which would go a long way in achieving his purpose. Mr. Joshi suggested that on every ballot paper should be printed a note saying that all members should vote in such a way as to give adequate representation to all engineering interests.

Mr. Bamji however pressed his own resolution for consideration. He was informed by the President that the resolution involved a change in the Bye-laws, which could only be made by a special meeting held for the purpose on the requisition of at least twenty members as prescribed in Bye-law 73. Mr. Bamji said that he would for the present agree to Mr. Joshi's suggestion, but would later on send a resolution and requisition for a special meeting to alter the Bye-laws. The meeting then unanimously adopted Mr. Joshi's proposal.

The Meeting terminated with a hearty vote of thanks to the Chair.

ANNUAL REPORT OF THE COUNCIL

For the Year ending 31st August, 1939.

1. MEMBERSHIP.—The change in membership is shown in the following tables :—

BENGAL CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31-8-38 ..	3	..	109	196	3	103	11	11	436
Additions :—									
Elected .	..	..	2	10	..	24	1	..	37
Transferred ..	..	..	2	9	..	1	..	..	12
Total Additions ..	..	.	4	19	.	25	1	..	49
Deductions :—									
Transferred ..	..	..	12	5	.	.	..	..	17
Deceased ..	1	..	..	2	..	..	..	..	3
Resigned ..	2	..	4	2	1	3	..	..	12
Struck off ..	..	..	1	4	..	10	..	..	15
Total Deductions ..	3	..	17	13	1	13	..	..	47
Membership on 31-8-39 ..	..	..	96	202	2	115	12	11	438

BOMBAY CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31-8-38	..	..	73	254	1	32	..	1	361
Additions :—									
Elected ..	..	..	6	18	..	4	.	..	28
Transferred .	..	.	3	13	.	1	.		17
Total Additions ..	..	..	9	31		5			45
Deductions :—									
Transferred ..	..	.	13	58	..	4	.	..	75
Deceased ..	..	.	1	1	..	..	..		2
Resigned ..	..	..	1	5	.		..		6
Struck off ..	..	..	1	2		8	.	..	11
Total Deductions ..	..	.	16	66	.	12	.	.	94
Membership on 31-8-39	..	..	66	219	1	25	..	1	312

HYDERABAD (DECCAN) CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31-8-38 ..	..	..	10	50	..	5	..	..	65
Additions :—									
Elected ..	..	..	..	1	..	..	..	..	1
Transferred ..	..	..		..	..	..	..	..	
Total Additions ..	..	..	..	1	..	..	..	..	1
Deductions :—									
Transferred ..	..	..	..	..	..	..	..	..	..
Deceased ..	..	..	..	..	..	..	.	..	..
Resigned ..	..	..	..	..	..	..	..	..	.
Struck off ..	..	..	..	..	..	1	..	..	1
Total Deductions ..	..	..	..	..	.	1	..	..	1
Membership on 31-8-39 ..	..	..	10	51	..	4	..	..	65

MYSORE CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31-8-38 ..	..	.	24	44	..	6	..	..	74
Additions :—									
Elected ..	..	..	..	1	..	..	..	..	1
Total Additions ..	.	..	24	45	..	6	..	..	75
Deductions :—									
Transferred ..	..	..	..	..	..	1	..	..	1
Resigned ..	..	..	1	..	..	..	..	..	1
Total Deductions ..	..	..	1	..	..	1	..	..	2
Membership on 31-8-39 ..	..	..	23	45	..	5	..	..	73

NORTH-WEST INDIA CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31-8-38 ..	2	..	32	87	..	21	2	..	144
Additions : –									
Elected ..	..	..	..	7	..	5	2	..	14
Transferred ..	..	..	4	3	..	3	1	..	11
Total Additions ..	..	..	4	10	..	8	3	..	25
Deductions :—									
Transferred ..	..	..	..	4	..	1	..	..	5
Deceased ..	..	..	1	1	..	..	..	..	2
Resigned ..	..	..	..	1	..	..	..	..	1
Struck off ..	..	..	..	1	..	..	1	..	2
Total Deductions ..	..	..	1	7	..	1	1	..	10
Membership on 31-8-39 ..	2	..	35	90	..	28	4	..	159

SOUTH INDIA CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31-8-38 ..	1	..	22	87	.	50	1	..	161
Additions :—									
Elected ..	..	..	3	8	..	13	..	..	24
Transferred ..	..	..	1	5	.	..	1	.	7
Total Additions ..	..	..	4	13	..	13	1	..	31
Deductions :—									
Transferred ..	..	..	2	11	..	2	..	..	15
Deceased .	..	..	..	..	..	..	.	..	.
Resigned ..	..	..	..	2	..	1	.	..	3
Struck off ..	.	..	..	2	.	9	..	..	11
Total Deductions ..	..	..	2	15	..	12	.	..	29
Membership on 31-8-39 ..	1	..	24	85	..	51	2	..	163

UNITED PROVINCES CENTRE.

Membership on 31-8-38 ..	1	..	30	76	..	12	9	.	128
Additions :—									
Elected ..	..	..	1	5	..	1	1	..	8
Transferred ..	..	..	1	8	..	1	..	..	10
Total Additions ..	..	..	2	13	..	2	1	..	18
Deductions :—									
Transferred ..	..	..	4	8	..	3	1	..	16
Deceased ..	..	..	..	2	..	..	..	..	2
Resigned ..	..	..	1	1	..	..	..	..	2
Struck off ..	..	..	..	6	..	..	..	..	6
Total Deductions ..	..	..	5	17	..	3	1	..	26
Membership on 31-8-39 ..	1	..	27	72	..	11	9	..	120

ABSTRACT

CENTRE.		Hon Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Bengal	..	.	.	96	202	2	115	12	11	438
Bombay	..	..	..	66	219	1	25	..	1	312
Hyderabad (Deccan)	..	..	..	10	51	..	4	..	..	65
Mysore		.	.	23	45	..	5	..	..	73
North-West India	..	2	..	35	90	..	28	4	..	159
South India	..	1	..	24	85	..	51	2	..	163
United Provinces	..	1	.	27	72		11	9		120
Outside India	..	1	2	89	7	.	.	1	..	100
Total	..	5	2	370	771	3	239	28	12	1,430

2. APPLICATIONS.—The total number of applications for membership received during the year was 336. Of these 115 were approved, 37 were approved subject to passing the necessary examination, 60 were rejected, 33 were returned being incomplete and 91 were under consideration at the close of the year.

3. COUNCIL.—(i) Mr. E. J. B. Greenwood was the President throughout the year.

(ii) The following Members retired from the Council:—

Under Bye-law 51.

Mr. E. J. B. Greenwood, Dewan Bahadur A. V. Ramalinga Aiyar, Dr. K. C. Chakko, Mr. S. N. Ghose, Mr. Mohsin Ali and Rai Bahadur Raj Narain.

Under Bye-law 53.

Mr. P. N. Banerjee, Dr. Geo. W. Burley, Mr. S. C. Majumdar and Col. C. Warren-Boulton.

(iii) The following Members resigned their membership of the Council:—

Mr. F. C. Griffin and Mr. A. F. Harvey.

(iv) The following Members were re-elected :—

Dr. K. C. Chakko, Mr. S. N. Ghose and Mr. Mohsin Ali.

(v) The following Members were newly elected :—

Mr. H. P. Bhaumik, O.B.E., Mr. John Chambers, O.B.E., Rao Bahadur C. V. Krishnaswamy Chetty, M.B.E., Mr. S. C. Majumdar, Mr. V. H. Sadarangani and Mr. R. K. Sarkar.

(vi) The following Members were co-opted :—

Dr. Geo. W. Burley, Mr. W. Gow, Mr. Siri Ram, Diwan Bahadur V. G. Shete, and Col. C. Warren-Boulton.

4. LOCAL CENTRES.—The Bengal Centre held 11 Ordinary General Meetings for the purpose of discussion of papers, delivery of lectures and discourses. The Annual General Meeting was held on the 9th December, 1938. A Conversazione was held on the 25th and 26th March, 1939 and several machines, scientific instruments, models and other useful engineering articles of local manufacture were exhibited. Two films—one depicting the history of the Tata Steel and the other—of road making in Bengal, and three social and news films were shown on the 25th and 26th March. Five visits were paid to works and places of engineering interest.

The Bombay Centre held 16 Ordinary General Meetings at which papers were discussed and lectures delivered. The Centre held its Annual Session from the 10th to 14th December, 1938. The Annual General Meeting was held on the 10th December and the Annual Dinner on the 12th December. Covers were laid for 120 persons including 34 ladies. Sir and Lady Gilbert Wiles were the Chief Guests at the Dinner. Five visits were paid to the engineering works and other places of interest.

The South India Centre held 5 General Meetings for discussion of papers, lectures and talks. The Annual General Meeting was held on the 24th November, 1938.

The United Provinces Centre held one Ordinary General Meeting for a discussion on Proctor's Pre-mix and Cement Concrete Roads. The Annual General Meeting was held on the 12th January, 1939. 5 Visits were paid to engineering works and on one occasion the members witnessed the demonstration of a gas driven lorry.

The N. W. I. Centre held 2 Ordinary General Meetings for lectures. The Annual General Session was held on the 25th and 26th February, 1939, and in connection therewith lectures and excursions were also arranged.

The Mysore Centre held 6 Ordinary General Meetings for discussion of papers and lectures. The Annual General Meeting was held on the 10th December, 1938. The Centre made 3 visits to engineering works during the year.

The Hyderabad Centre was inagurated on the 15th November, 1938 by The Rt. Hon'ble Nawab Sir Hyder Nawaz Jung Bahadur, President of H.E.H. the Nizam's Executive Council. The Centre held 6 Ordinary General Meetings for discussion of papers and lectures, and paid a visit of inspection.

5. BRITISH STANDARD SPECIFICATIONS.—This Institution continued to act as the Indian National Committee of the British Standards Institution of London. 129 draft specifications were received for comments. Of these 108 were disposed of and 21 were under consideration at the close of the year.

Mr. E. J. Hogben continued to act as Adviser to the Council on draft British Standard Specifications. The Council offers its thanks to him for the valuable assistance rendered by him.

6. WORLD POWER CONFERENCE.—This Institution continued to act as the Indian National Committee of the World Power Conference. Mr. E. J. B. Greenwood was nominated as one of the Vice-Presidents of the Conference in place of Col. F. C. Temple, C.I.E. Mr. C. I. Stabler attended a meeting of the Executive Council of the Conference at Zurich on 10th July, 1939 as a representative of this Institution.

It was decided at the meeting of the International Executive Council of the World Power Conference held in Washington in 1936 that the next Plenary Meeting of the World Power Conference and the International Commission on Large

Dams would be held in Tokyo in 1942. The Central Board of Irrigation suggested to the Government of India that these two meetings be held in India should Japan withdraw her invitation. The Government of India asked for the opinion of this Institution on the proposal and also information on the following points, *viz.*, (1) the advantage that would accrue to India, (2) the manner in which the Institution, as the National Committee, upon whom the main work of organization would devolve, proposed to meet the difficulties regarding accommodation, entertainment and visits of the delegates, (3) arrangements to render the proceedings intelligible to the foreign delegates and (4) a fairly detailed estimate of cost and how the same would be met. The Council appointed a Sub-Committee consisting of Mr. H. P. Bhaumik, O.B.E., Mr. S. N. Ghose and Mr. S. C. Majumdar to go through the matters. The necessary reply has been sent to the Government of India. The Council thanks the members of the Sub-Committee for the trouble they took in this connection.

7. INTERNATIONAL ELECTROTECHNICAL COMMISSION.—This Institution continued to act as the Indian National Committee of the Commission. Mr. A. C. Banerjee acted as the Council's Adviser on Electrotechnical matters. The Council takes the opportunity of thanking him for the valuable assistance rendered by him.

8. ANNUAL SESSION.—(i) The Nineteenth Annual Session was held at Benares from 13th to 16th January, 1939.

(ii) The Annual General Meeting was presided over first by Mr. Fakirjee E. Bharucha and then by Mr. E. J. B. Greenwood who delivered the Presidential Address. Several special resolutions were passed. These were embodied in the Minutes of Proceedings of the Annual General Meeting which have already been supplied to the members. The following is the summary of the action taken by the Council on those special resolutions :—

(*a*) It was decided to issue monthly Journals which would include (i) original papers and communications on engineering questions, (ii) resume' of the activities of the Institution together with those of its Local Centres, (iii) summaries and reports of research work in

engineering and other engineering undertakings in India and outside and (iv) all matters that are likely to be of interest to the engineering profession. The Council also decided to appoint a wholetime Technical Secretary to edit the Journal. The post was advertised and the applications are being scrutinized. The Council hopes to make the actual appointment very shortly.

(*b*) The resolution regarding the rate of depreciation on the Institution building at Calcutta was referred to Messrs. Price, Waterhouse, Peat & Co., the Institution's Auditors. They considered that in view of the fact that the building was erected on a leasehold land, the proposed rate of ½ per cent was insufficient. In their opinion the building should be written off after the period of the first lease (*i.e.*, 90 years). In other words the balance on the Premises Account as at 31st August 1938, *viz.*, Rs. 66,181-9-11 would be written off over the unexpired period of the lease (*i.e.*, 82 years). The required depreciation would therefore amount to Rs. 807 per annum or approximately 1¼ per cent. The Council agreed with the above view and adopted the rate of 1¼ per cent.

(*c*) A Sub-Committee consisting of the following members was formed to go into the question of the proposed re-orientation of the engineering curricula of the Indian Universities and to report what changes are necessary in the engineering education to suit the modern conditions :—

Mr. A. C. Banerjee, Mr. S. C. Bhattacharjee, Dr. K. C. Chakko, Mr. B. S. Chetti, Mr. A. N. Sen, Mr. P. E. Golvala, Mr. B. Krishnaswami Iyengar, Mr. S. B. Joshi, Mr. B. R. Kagal, Mr. Mohsin Ali, Mr. R. P. Mathur, Mr. E. K. Ramaswami, Dr. S. P. Raju and Mr. Samiullah Shah.

(*d*) The proposal for the formation of an Information Bureau at headquarters was referred to a Sub-Committee consisting of Rai Bahadur B. P. Varma, Mr. B. R. Kagal, Khan Bahadur A. G. Khan and Mr. T. R. S. Kynnersley.

(*e*) The Council considered the suggestions regarding the framing of conduct rules for Corporate Members and the sale of adulterated cement, and referred the matter to a Sub-Committee consisting of Mr. P. P. Adalja, Mr. S. B. Joshi and Dr. Shiv Narayan.
The reports of these Sub-Committees have not yet been received.

(*f*) A Sub-Committee consisting of Mr. S. B. Joshi, Mr. T. R. S. Kynnersley and Mr. N. V. Modak was formed to go through the Bill for Registration of Engineers in India. The report is under consideration of the Council.

The Council takes this opportunity of thanking the Members of the Sub-Committee for the trouble they took in the matter.

(*g*) With regard to the question of recognition of the Corporate Membership and the A.M. examination of this Institution by the Institutions of Civil, Mechanical and Electrical Engineers, London, a Sub-Committee with the following Members, *viz.*, Mr. Fakirjee E. Bharucha, Mr. T. R. S. Kynnersley, Mr. N. V. Modak and Mr. S. B. Joshi was formed to carry on negotiations with the three Institutions. The Sub-Committee drafted a representation to the three Institutions and submitted it to the Council for approval. The Council approved it and instructed the Sub-Committee to forward it through the London Committee of the Institution of Engineers (India). The Sub-Committee have since forwarded the representations to the three Institutions through the London Committee.

(*h*) As regards the resolution protesting against the policy of employers of engineers, of giving preference to the degrees and diplomas of foreign universities, inspite of the present high standard of Indian degrees and diplomas in Engineering, copies of the resolution were sent to the Federal and Provincial Public Service Commissions and also to the Provincial Governments. At the suggestion of the Governments of Bengal and Orissa copies were sent to all

Municipalities and District Boards in those two provinces. A Deputation on behalf of the Bombay Centre waited upon the Hon. Minister for P. W. D. in this behalf. The Hon. Minister assured the deputationists that the recruitment rules of the Government of Bombay were being revised and that the Government of Bombay did not give preference to degrees and diplomas of foreign universities.

(*i*) A similar action was taken on the resolution impressing upon the local Governments, Municipalities and other public bodies the advisability of consulting this Institution on questions affecting engineering.

(iii) The Annual Dinner was held at the Mint House of H. H. the Maharaja of Benares. Covers were laid for 72 persons.

(iv) The members visited the Sindhya Ghat reconstruction, the Drainage and Water Works near Asighat, Sarnath, Hewett Dam and the Swadeshi Silk and Ribbon Mills.

(v) Two papers were discussed, *viz.* (1) Dehra Dun Water Supply—Bandal Nadi Extension written by Mr. H. G. Trivedi and (2) Lacey's Theory and the Deccan Canals written by Rao Saheb N. S. Joshi.

9. EXAMINATIONS.—Only one candidate appeared at the Preliminary Examination and he failed. 16 candidates appeared at Section A of the Associate Membership Examination and all of them failed. 18 candidates appeared at Section B and 10 passed. 3 candidates appeared at Section C and all of them passed.

The Examination Regulations were revised.

A new rule regarding admission of ex-students into Sections A or B of the Associate Membership Examination was inserted. According to this rule those ex-students, who had already passed Section A and who wished to pass Section B or *vice versa* would be entitled to appear at Section A or B as the case may be, within two years from the date they ceased to be students under Bye-law 29.

Mr. S. C. Bhattacharjee, a Corporate Member, suggested a revision of the syllabus for "Technical Electricity" and for "Electrical Engineering". After taking the opinion of the

Examinations Committee, the Council formed a Sub-Committee consisting of Mr. H. P. Bhaumik, O.B.E., Mr. A. C. Banerjee and Rai L. C. Bose Bahadur to go into the question. The Sub-Committee re-drafted the syllabii which were accepted. The Council thanks the Members of the Sub-Committee for the trouble they took in the matter.

10. RECOGNITION OF THE A. M. EXAMINATION OF THIS INSTITUTION.—The Council is glad to announce that there was an addition to the list of Governments recognizing the above Examination. The Government of Orissa recognized the passing of Sections A and B of the Associate Membership Examination as equivalent to the Degree of an Engineering College.

The Governments of the Punjab, Bengal, United Provinces, Central Provinces, Burma and Travancore, and also the Federal Public Service Commission have already recognized the Examination.

11. RECOGNITION OF OTHER EXAMINATIONS BY THIS INSTITUTION.—The B.Sc. (Eng.) Degree of the Punjab University was recognized for the purpose of exemption from Sections A & B of the Associate Membership Examination.

The recognition hitherto given to the Associateship in Engineering of the Sheffield University and the Associateship in Mechanical Engineering of the Bengal Engineering College for the purpose of exemption from Sections A & B of the Associate Membership Examination was withdrawn.

12. PAPERS.—The following papers were accepted as Institution papers :—

(a) "Modern Tendencies in Design and Construction of Track" by Mr. A. Vasudevan.

(b) "Ganges Flood and its Lessons" by Mr. S. C. Majumdar.

(c) "Economics of Deccan Canals—Selection of Water Depth" by Rao Saheb N. S. Joshi.

(d) "Rontgenology in Reinforced Concrete" by Dr. M. A. Korni.

13. PRIZES.—H. E. the Viceroy's prize for the year 1937-38 was awarded to Mr. A. Vasudevan for his paper, "Modern Tendencies in design and construction of track." The Institution Prize for Students (Sir R. N. Mookerjee Prize) for the Bombay Centre was awarded to Mr. M. Seshadriengar for his paper, "Applications of the principles of rigid frames to structures." The Railway Board Prizes were not awarded.

14. SHIPBUILDING IN INDIA.—Mr. S. B. Joshi suggested that a Sub-Committee be formed to investigate the possibility of Shipbuilding in India. This suggestion was accepted and the necessary action taken.

15. THE INSTITUTION'S CO-OPERATION IN THE WAR.—A letter was addressed to the Government of India, conveying the readiness of this Institution to co-operate in every scheme calling for engineers and engineering materials, and placing at their disposal the accumulated experience and facilities of the Institution.

The Government of India expressed their warm appreciations of the offer.

16. SIR R. N. MOOKERJEE MEMORIAL.—The marble bust supplied by the sculptor having been found to be defective, it was rejected. A fresh bust has been received and it will be installed shortly.

17. HONOURS.—The Council offers its hearty congratulations to the following members on whom Honours were conferred during the year :—

Sir James Pitkeathly	..	K.C.I.E.
Rai Bahadur P. L. Dhawan	..	C.I.E.
Mr. L. B. Green	..	O.B.E.
Mr. A. K. Thoms	..	M.B.E.
Mr. T. K. Mirchandani	..	M.B.E.
Mr. J. D. Paterson	..	M.B.E.
Mr. N. K. Mitra	..	Rai Bahadur.
Rai Saheb S. N. Roy	..	Rai Bahadur.
Mr. A. C. Mukherjee	..	Rai Bahadur.
Mr. P. L. Gupta	..	Rai Bahadur.
Mr. D. P. Rohatgi	..	Rai Bahadur.

18. DONATION.—A donation of Rs. 25 was received from Mr. S. B. Joshi.

19. PROVIDENT FUND FOR THE STAFF.—It was decided to start a Provident Fund for the wholetime staff of the Institution including those of Local Centres. Necessary rules were framed and submitted to the Commissioner of Income-Tax for approval. The rules will be brought into force as soon as his approval is received. The Council takes the opportunity of thanking Mr. S. K. Chakravarti, Mr. J. N. Das Gupta and Col. C. Warren-Boulton, Members of the Sub-Committee, for going through the Draft Rules.

20. ACCOUNTS.—Copies of the accounts of the Local Centres and the audited accounts of the Institution are appended.

BENGAL CENTRE.

INCOME

	Rs.	A.	P.
To Contribution by the Institution	4,121	14	9
Rs.	4,121	14	9

EXPENDITURE

	Rs.	A.	P.
By Rent & Taxes	1,942	8	0
,, Establishment	360	0	0
,, Stationery & Printing	207	13	0
,, Postage & Telegram	194	4	0
,, General Meeting	172	8	0
,, Annual General Meeting	170	8	6
,, Books & Periodicals	1,058	9	9
,, Miscellaneous	15	11	6
Rs.	4,121	14	9

BOMBAY CENTRE.

INCOME

	Rs.	A.	P.
By Cash balance as per last year's Statement	3	9	3
,, Bank balance as per last year's Statement	323	5	11
,, Stamps in hand as per last year's Statement	0	5	0
,, Funds received from the Parent Institution	3,300	0	0
,, Sale of old books etc.	1	8	0
,, Amount for Sir Rajendranath Mookerjee Prize received from the Headquarters	50	0	0
Rs.	3,678	12	2

EXPENDITURE

	Rs.	A.	P.
To Salaries	1,034	0	0
,, Postages	222	1	0
,, Printing Charges	86	4	0
,, Stationery	57	0	0
,, Conveyances	1	3	6
,, Rents	1,200	0	0
,, Lighting & Fans	14	3	6
,, Annual Meeting Expenses	249	4	0
,, Ordinary Meeting Expenses	164	13	9
,, Charges General	106	13	0
,, Books and Periodicals	163	5	0
,, Prize awarded to Mr. M. Seshadriengar	50	0	0
,, Furniture	Nil		
,, Unforeseen Contingencies	Nil		
,, Cash in Hand	10	14	0
,, Cash at Bank	317	9	5
,, Stamps in Hand	1	5	0
Rs.	3,678	12	2

HYDERABAD CENTRE.

INCOME.

	Rs.	A.	P.
Contribution by the Institution	1,500	0	0
Grand Total Rs.	1,500	0	0

EXPENDITURE.

		Rs.	A.	P.
1. Establishment		441	10	10
2. Postage and Telegrams		34	2	9
3. Stationery and Printing		82	5	4
4. Furniture and Fittings		606	5	1
5. Rents and Taxes		Nil		
6. Lighting and Fans		Nil		
7. Books and Periodicals		62	4	9
8. Charges general :—				
General charges ..	Rs. 85 10 5	249	3	3
Inaugural Meeting charges ..	Rs. 163 8 10			
Total ..		1,476	0	0
Balance with the Imperial Bank of India, Hyderabad-Dn. ..		13	0	11
Balance on hand		10	15	1
Grand Total Rs.		1,500	0	0

MYSORE CENTRE.

INCOME.

	Rs.	A.	P.
Opening Balance on 1st September, 1938	79	11	4
Amount Received from Calcutta	1,170	0	0
Grand Total Rs.	1,249	11	4

EXPENDITURE.

	Rs.	A.	P.
1. Contribution to the Mysore Engineers' Association ..	336	0	0
2. Establishment	384	0	0
3. Postage	21	2	0
4. Books and Periodicals	439	14	0
5. Printing and Stationery	12	9	0
6. General Meetings	53	11	0
7. Unforeseen	2	4	0
Total Rs.	1,249	8	0
Closing Balance Rs.	0	3	4
Grand Total Rs.	1,249	11	4

NORTH-WEST INDIA CENTRE

INCOME

	Rs. A. P.
By Balance brought Forward :—	
In Hand	13 9 0
At Bank	190 10 0
By Amount received from the Secretary, the Institution of Engineers (India) Calcutta :—	
On 7-10-1938	200 0 0
On 23-2-1939	200 0 0
On 25-3-1939	200 0 0
On 12-6-1939	200 0 0
On 28-6-1939	200 0 0
On 13-7-1939	800 0 0
On 30-8-1939	95 0 0
Total Rs.	2,099 3 0

EXPENDITURE

		Rs. A. P.
To rent of Building		215 14 6
,, Water and Electric Energy charges		139 10 0
,, Printing and Stationery		135 1 0
,, Salaries and Wages		390 0 0
,, Postage and Stamps		77 10 3
,, Books and Periodicals		205 10 0
,, Furniture		280 4 0
,, Miscellaneous petty contingent expenses		44 10 0
,, Discount Charged by the Bank		7 4 0
,, Balance carried over :—		
In Hand	Rs. 12 2 6	603 3 3
At Bank	Rs. 591 0 9	
Total Rs.		2,099 3 0

SOUTH INDIA CENTRE

INCOME

		Rs. A. P.
Opening Balance :—		
Bank Balance	Rs. 298 11 2	303 10 2
Cash on Hand	Rs. 4 15 0	
Received from the Secretary Calcutta on :—		
25th October, 1938		350 0 0
30th January, 1939		350 0 0
4th Sept., 1939 by cheque due for the above year		330 0 0
Grand Total Rs.		1,333 10 2

EXPENDITURE

		Rs. A. P.
Rent for the Premises		350 0 0
Salary of Clerk		180 0 0
Wages of Peon and Caretaker		24 0 0
Electric current		21 0 0
Printing charges		54 3 11
Stationery charges		17 2 0
Postage		75 6 3
Telephone charges		1 4 0
Bus and Conveyances		14 6 4
Bank commission on cheques		1 6 0
Bank ledger fees		5 0 0
General Meeting expenses including Teas		54 6 0
Total Rs		798 2 6
Bank balance on 31-8-39 :—Rs.	195 11 3	535 7 8
Remittance from Calcutta :—Rs.	330 0 0	
Cash on hand :—Rs.	9 12 5	
Grand Total Rs		1,333 10 2

UNITED PROVINCES CENTRE

INCOME

		Rs.	A.	P.
Opening Balance on September 1, 1938		112	8	9
Received from Parent Institution, Calcutta		2,184	0	0
Price of books through Parent Institution		81	10	0
Library accounts				
Recovered postage on books issued out-stations	Rs. 1/7/-			
Realized fines on books overdue	Rs. 5/2/-	18	9	0
Library Admission Fee	Rs. 12/-			
Total Rs.		2,396	11	9

EXPENDITURE

		Rs.	A.	P.
1 Books and Periodicals		486	15	0
2. Salaries and Wages		951	5	0
3. Postage and Telegrams		72	14	0
4. Printing and Binding		158	13	0
5. Stationery		39	9	9
6. Annual General Meeting		93	0	0
7. Rent of Library Building and Lease charges of the plot of land		304	0	0
8. Furniture and Fittings		106	1	0
9. Railway freight, T.A., carriage of records etc.		42	2	6
10. Lighting and Fans		108	3	0
11. Contingencies :—				
Bank charges	Rs. 7/8/-			
Repairs to Cycle, Typewriter etc.	Rs. 18/9/6	32	3	3
Miscellaneous	Rs. 6/1/9			
Total expenditure Rs.		2,395	2	6
*Balance in hand		1	9	3
Total Rs.		2,396	11	9

*Details of balance :—

Cash in Allahabad Bank Ltd., Lucknow	Rs.	1	9	0
Cash in hand	Rs.	0	0	3
	Rs.	1	9	3

The Institution of Engineers (India).

BALANCE SHEET AS AT 31ST AUGUST, 1939.

LIABILITIES & SUNDRY CREDIT BALANCES.

	Rs. A. P.	Rs. A. P.	Rs. A. P.
Permanent Reserve Fund—			
As per last Account		1,10,793 6 3	
Add: Entrance Fees	2,315 0 0		
Composition Fees	1,234 0 0		
Transfer Fees	80 0 0		
Profit on Redemption of 5% Government Paper 1939-44	4,451 14 0	8,080 14 0	1,18,874 4 3
(*Vide* Resolution No. 29 of Council Meeting No. 243.)			
Donations—			
As per last Account		3,778 7 7	
Add: Amount received during the year		25 0 0	3,803 7 7
Funds—			
Building Fund—			
As per last Account		80,613 15 2	
Sir R. N. Mookherjee Memorial Fund—			
As per last Account		2,133 11 3	82,747 10 5
Liabilities—			
For Expenses		350 0 0	
Viceroy's Prize		500 0 0	
B. E. S. A. Allowance Fund		1,456 4 3	
National Electro-Technical Committee for India		83 4 2	2,389 8 5
Advance Payments—			
Subscriptions		852 0 0	
Examination Fees		180 0 0	
Sundries		55 0 0	1,087 0 0
Employees' Deposits—			
Current Account with Imperial Bank of India (As per Contra)		100 0 0	
Post Office Cash Certificates (as per Contra)		1,059 0 0	1,159 0 0
Carried over			2,10,060 14 8

ASSETS & SUNDRY DEBIT BALANCES.

	Rs. A. P.	Rs. A. P.	Rs. A. P.
Building—			
As per last Account		80,130 10 6	
Less: Depreciation as per last Account	13,949 0 7		
Provided this year	827 4 0	14,776 4 7	65,354 5 11
Furniture and Fittings—			
As per last Account	24,347 9 10		
Additions during the year	1,105 9 1	25,453 2 11	
Less: Depreciation as per last Account	10,595 15 10		
Provided this year	681 8 6	11,277 8 4	14,175 10 7
Book Debts—(Unsecured)—			
Subscriptions considered good		5,684 13 9	
Subscriptions considered doubtful		1,997 4 0	
Sundries		764 1 6	8,446 3 3
Permanent Reserve Fund—(As per Contra)—			
Investments—At Cost—	Rs. A. P.		
$4\frac{1}{2}$% Loan 1955-60 for	14,000 0 0	13,228 5 0	
4 % Loan 1960-70 for	84,400 0 0	93,333 0 0	
3 % Loan 1941 for	9,000 0 0	9,273 5 0	
	1,07,400 0 0	1,15,834 10 0	
Note: Market Value Rs. 1,16,872-4-0.			
Cash with Imperial Bank of India—			
On Current Account—			
Capital Account	1,486 0 3		
Revenue Account	1,553 10 0	3,039 10 3	1,18,874 4 3
Investments—At Cost—			
4% Loan 1960-70 for Rs. 27,700/-		31,210 12 0	
(*Note:* Market value Rs. 30,106-7-0)			
Post Office Cash Certificates deposited by Cashier Rs. 1,200/- (As per Contra)		1,059 0 0	32,269 12 0
Interest accrued on Investments			2,467 10 8
Carried over			2,41,587 14 8

	Rs. A. P.	Rs. A. P.
Brought forward		2,10,060 14 8
Library Deposits		25 0 0
Income and Expenditure Account—		
As per last Account	29,563 8 6	
Add : Excess of Income over expenditure	6,977 2 10	
Adjustments referring to former period	269 2 0	36,809 13 4
	Rs	2,46,895 12 0

	Rs A. F	Rs. A. P.	Rs. A. P.
Brought forward			2,41,587 14 8
Cash and other Balances—			
With Imperial Bank of India—			
On Current Accounts—			
Revenue Account		3,661 9 3	
Employees' Security Deposit Account (as per Contra) ..		100 0 0	
In hand		53 7 11	
With Local Centres—			
With Banks on Current Accounts	1,119 2 2		
In hand	373 10 0	1,492 12 2	5,307 13 4
		Rs	2,46,895 12 0

AUDITORS' REPORT TO THE MEMBERS OF THE INSTITUTION OF ENGINEERS (INDIA).

We have audited the Balance Sheet of the Institution of Engineers (India) dated 31st August, 1939 and above set forth, and the annexed Income and Expenditure Account for the year ended 31st August, 1939 with the Books and Accounts as kept in Calcutta, in which are incorporated the certified Returns from the Local Centres, and have obtained all the information and explanations we have required. In our opinion such Balance Sheet and Income and Expenditure Account are drawn up in conformity with the Law and the Balance Sheet exhibits a true and correct view of the state of the Institution's affairs according to the best of our information and the explanations given to us and as shown by the Books of the Institution. In our opinion Books of Account have been kept as required by Law.

PRICE, WATERHOUSE, PEAT & CO.
Chartered Accountants
Registered Accountants.
} Auditors.

CALCUTTA.
15th December, 1939

The Institution of Engineers (India).

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st AUGUST, 1939.

EXPENDITURE.

	Rs	A.	P.	Rs.	A.	P.
To Salaries and Wages	15,540	0	7			
,, Bad Debts	2,157	2	0			
,, Stationery and Printing	4,336	0	9			
,, Postages and Telegrams	1,721	12	0			
,, Conveyances	204	4	7			
,, Diploma	130	5	6			
,, Journal	3,891	9	9			
,, Telephone charges	189	1	0			
,, Bulletins	1,230	1	0			
,, Lighting and Fans	375	8	0			
,, Examinations	338	1	6			
,, Books and Periodicals	2,472	2	9			
,, Rent and Taxes	6,120	14	6			
,, London Committee Expenses ..	360	0	0			
,, General Meeting	605	15	7			
,, Annual General Meeting ..	1,346	3	9			
,, Issue of Papers	2,961	15	3			
,, Repairs to Institution Building .	285	8	6			
,, Audit Fees	350	0	0			
,, Depreciation	1,508	12	6			
,, Charges General .. .	1,185	15	5			
,, Sir R. N. Mookerjee Prize .	50	0	0			
				47,361	6	11
,, Balance being excess of Income over Expenditure transferred to Balance Sheet				6,977	2	10
			Rs.	54,338	9	9

INCOME.

	Rs.	A.	P.
,, By Subscriptions	47,507	4	0
,, Sale of Standard Specifications ..	542	7	1
,, Interest	6,118	13	8
,, Advertisement	66	6	0
,, Sale of Publications	103	11	0
Rs.	54,338	9	9

PRESIDENTIAL ADDRESS

BY

KHAN BAHADUR M. ABDUL AZIZ, C.I.E.

PRESIDENT 1939-40.

Gentlemen,

I deeply appreciate the honour you have done me by electing me your President for the ensuing year. I wish I had the power to convey to you adequately the feelings of gratitude, pride and humility, with which my heart is full on the occasion. An honour so high, conferred by my associates has given me a sense of elation, but the realisation of the obligations attached, and the conciousness of my own shortcomings, have made me feel diffident. The confidence of your co-operation, help and advice, however, has encouraged me in accepting the responsibilities you have chosen to place on me. I assure you that I will endeavour to conduct the affairs of the Institution, as best as I can and try to maintain the traditions established by my distinguished predecessors.

2. The object of the Institution as defined in the Royal Charter are "to promote the general advancement of engineering and engineering science and their general application in India." I wish to draw your attention to the fact that these objects are inspired entirely by unselfish motives, and are directed towards the advancement of social order. They recognise that engineering is a profession, and imply the obligation of the professional man, to devote to the good of society, some part of the advantages, which it has enabled him to obtain. This, gentlemen, should be the guiding principle of a professional life.

The primary function, then, of this Institution, so far as its members are concerned, is the maintenance of their high professional standing with social advancement as the chief object in view.

3. It is, however, natural and quite proper for professional men to demand reasonable economic benefits for themselves and their dependants. The Institution may, therefore, rightly interest itself into the economic state of its members, though such interest should be regarded only as its secondary concern. Any action regarding this, taken by the Institution, should be in a spirit of rendering benefit to the society as a whole, and not in the interest of a particular class, or individuals, at the cost of society in general. I stress this point because for some time past there has been a movement among the members to promote legislation for the registration of engineers. A draft of a bill was placed before the general meeting of the Institution last year. The principle of the bill was accepted and a committee was appointed to examine it. I earnestly appeal to you, gentlemen, to reconsider your decision, for, I believe, that registration will not be in the interest of our profession, nor indeed in that of society as a whole. The profession of engineering has not yet sufficiently developed in this country, and facilities for education and practical training are still very limited. Registration necessarily means restriction, and I think, it is not desirable that the number of engineers should in any way be limited. In my opinion restriction by legislation, registration, or in any other form, at this stage of our development will be a shortsighted policy, and will damage our profession in the long run. Further, the proposal savours of the guild or trade union spirit, which is inconsistent with the true ideals of a professional group. So far as the members are concerned it is more important for the Institution, and consistent with its ideals of public benefit, to set up standards of attainments, and evolve principles of conduct, to serve as guides to all engineers, whether in Government service, private practice or industrial organizations. If these standards and codes are accepted by the public, no need for registration will exist. After all, the status of an engineer does not depend on legal devices, but on the respect and confidence he can command from the public he serves.

4. Arising out of the main objects of the Institution, is its most important obligation to ensure that the education and training of students in engineering is on right lines, and is in accordance with the needs of the profession in this country. Last year Mr. Kagal rightly emphasised this point, and proposed

the formation of a committee for suggesting alterations in the curricula of technical institutions. Its report will be available in this session. I have no desire to forestall your discussion, but wish to point out that revision of the technical curricula alone will not suffice. The engineer of to-day requires some knowledge of economics also. Not only that. The advent of democracy in this country has made it necessary for him to possess a fair grounding in other social sciences as well, such as Civics and Psychology. Literature on the subject of engineering economics of this country practically does not exist. In my opinion it is time that this Institution encouraged research on this subject, and made its results available to the profession. To illustrate my point I quote an example. The possibilities of new irrigation works, directly remunerative to the state in this country, are now almost exhausted. By its very nature, however, an irrigation work is never unremunerative to the state because of its indirect benefits, such as larger employment, increased freight for railways, more trade leading to increased income-tax and excise duties, higher land revenue, lower expenditure on famine relief and so on. No attempt has ever been made to correctly assess the monetary values of many of these indirect benefits. Unless these are assessed and credited to their proper sources, further development of irrigation works is likely to suffer.

5. Another question I wish to place before you is the position of the students admitted to the Institution. They come from two classes, (i) students who are still in colleges or have just left them after completing their courses, and are undergoing practical training and (ii) those, who, without joining any recognised educational institution, or having got partial training in them, have secured minor positions in Government service, or industrial concerns, and are ambitious to rise to the full status of engineers. So far as purely technical training is concerned, the former category is looked after by the Colleges, but the latter also needs some general guidance, and, that, I hold, is the business of this Institution to provide. Our chief object, however, in admitting students to the Institution is to bring them in contact with mature minds in the profession, who are interested in the education of their likely successors. They alone can inculcate the true professional spirit in them, show them the proper function of engineers in society, and their responsibilities to its various sections.

Except providing a few small libraries, and holding examinations to test the technical qualifications of students, we have so far done little to help them. To bring them in contact with professional men by means of meetings and discussions is the function of local centres, but we all know that meetings held by these centres have often been too few in the past, and the papers read and discussions held, have not generally been up to the correct standard. The report of the council for 1939 also shows that, excepting Bengal and Bombay centres, the position in this respect has everywhere been unsatisfactory.

I suggest that we appoint a permanent education committee, whose function should be firstly, to remain in constant touch with technical institutions in this country, and advise them regarding their curricula from time to time, and, secondly, to devise ways and means to advise and supervise the education of the students of this Institution.

6. We owe a debt of gratitude to the founders of this Institution for creating an organization for the engineering profession as a whole. In spite of its various specialized branches, the Engineering profession is one, and the social and economic problems of all its different branches are identical. A central national organization for dealing with such problems was necessary. Nevertheless, for the advancement of technical knowledge, a division of labour within the general body is essential. In my opinion, we have now reached a stage, where the formation of specialized sections is advisable in the interest of technical progress. I am afraid the Institution has not so far been able to do much in this direction. It is true, we have already formed a few technical committees like the one for standardization, but, I think, that similar permanent committees should now be formed for the following specialized branches of engineering: (i) Irrigation, (ii) Railways, (iii) Electrical Engineering, (iv) Mechanical Engineering, (v) Sanitary Engineering, and (vi) Chemical Engineering.

These committees should function either at the headquarters of the Institution, or at other suitable centres. The activities of all these committees should be co-ordinated by the technical Secretary at the headquarters, and published in

the monthly technical journal, a proposal for starting which has already been approved. Later on, as need arises, more committees may be formed to deal with other specialized subjects.

7. Our membership has not made much improvement during 1939. It has increased only by 25 members, sixteen of whom are students and companions. The total as it now stands is 1,430. In view of the number of engineers in the country and of its size, I consider, that the profession is not supporting the Institution adequately, and a serious effort by members is needed to increase membership without lowering our standards.

8. During the nineteen years of its existence, the Institution has done much valuable work in overcoming initial difficulties, and consolidating its position. If, in spite of this, I have indulged in mild criticism of its affairs, I assure you, that it is in no carping spirit. I think it is always desirable to make searching self-examination occasionally, to ensure statisfactory progress.

9. Engineering activity in India has so far been chiefly confined to irrigation and communications. Although our irrigation systems, especially those in the Punjab, are the most extensive and unrivalled in the world, yet 70 per cent of the total cropped area in this country has no facilities whatsoever for irrigation. Most of our resources for providing flow irrigation from rivers have already been or will soon be exhausted. For further extension, we shall have to rely to a large extent on pumping from underground reservoirs or deep rivers. This needs cheap power.

10. During the past two decades India has made fair progress in industrialisation, but this is still in its infancy, and the rate of progress needs acceleration. The European war, now in progress, has not only demonstrated our present helplessness in maintaining a steady supply of many articles required for use in daily life, but has also afforded a unique opportunity for further advancement in industrialisation. Supply of cheap power is essential for this purpose. Except near the coal-fields of Bihar and Bengal, this is only possible by harnessing water-falls, and the resources of this country

in this respect are enormous. A complete and correct estimate of these is not available. Several estimates, varying from 8 to 12 million kilo-watts, have been published, but they are all based on guess work and appear to be rather conservative. Out of such vast resources less than half a million kilo-watts or about 4 per cent only have so far been developed. The three Tata Schemes in Bombay represent half of the total installed water-power in India. The rest of the country has taken advantage of only 2 per cent of nature's generous gift of water-power.

11. Industries like textiles, sugar, cement and steel, which could be developed by thermal power, have made a fair headway, but electrö-chemical and electro-thermal processes, which play a large part in the manufacture of products, required in every day life, have not yet been even started. The importance of electro-chemical and electro-thermal processes cannot be over-emphasised. They include such industries, as the manufacture of inorganic fertilisers, chemical nitrogen, potash, caustic soda, chlorine, aluminium, copper, zinc, and certain other metals; melting, refining, alloying and heat treating of iron, steel, brass and ferro-alloys. Without the production of these, scientific agriculture, and manufacture of machinery, armaments and materials for national defence, and other important commodities, is not possible. Most of the articles I have named are not obtainable by any practicable means except cheap electric power.

12. The power requirements of electro-process industries are very large, and the cost of electric power is necessarily a high proportion of the value of finished articles. In most of the other industries, the cost of power in Europe and America is two to three per cent of the selling price of the finished product, but in electro-process industries, the power cost, at very low prices ranging fom 1·5 to 3 pies per unit, amounts from ten to fifteen per cent of the sale value of products. For instance, in the case of aluminium, power at 1·5 pies per unit accounts for 15 per cent of the sale price of the metal. Similarly, for caustic soda, power at 3 pies per unit is 11 per cent of the sale value. On account of the large requirements and cost of power, electro-process industries are bound to be located in areas where power can be purchased cheaply and not merely at places where raw materials are available.

13. The Himalayan valleys and foot hills, where large perennial rivers and their numerous tributaries descend on to the plains, afford great scope for the development of cheap power. Most of these places are situated within easy transmission distances of centres of population in Upper India, which should provide ready markets for electro-process manufactures and electrical energy. An interesting scheme of this nature has recently been investigated on the Jumna river. It contemplates the development of minimum continuous power of about 1,25,000 kilo-watts in four stages, at places within fifty miles of Saharanpur. The power houses and transmission lines are all proposed to be located in the plains. It is estimated that, with a 50 per cent load factor, the cost per unit delivered within a hundred miles of the generating stations will be about 1·5 pies. Mr. Meares estimated that a minimum continuous power of 2,40,000 kilo-watts could be generated on the Sutlej within some forty miles of the Jumna generating stations. It appears probable that both these rivers can ensure the generation of an average block of power amounting to half a million kilo-watts for consumption in the well-populated country between Ludhiana and Aligarh. Saharanpur lies in the centre of this tract, and is one of the best railway centres in Upper India. There is no reason why this tract within economic transmission distance of Saharanpur should not be highly industrialised if cheap power for electro-process manufactures is made available. It is already attracting industries from outside on account of the Ganges Canal Hydro-Electric Grid, but the power available is at present very limited.

14. I have already referred to the necessity of cheap power for agricultural purposes. An interesting and successful demonstration of this on a large scale is provided by the Ganges Canal Hydro-Electric Grid in the United Provinces. It owed its inception to one of our Past Presidents, Raja Jwala Prasad. The preparation of designs and execution of works were carried out by another distinguished member of this Institution, Sir William Stampe, and the details of the project have been published in his various reports, papers and lectures. Briefly it comprises seven Hydro-Electric generating stations on the falls of the Upper Ganges Canal, the total installed capacity of which is 18,900 kilo-watts, and a steam station at Chandausi, with an installed capacity of 9,000 kilo-watts. The transmission

system is 4,525 miles in length and includes 262 sub-stations in urban areas, and 1,662 in rural areas. The connected load is roughly 35,000 kilo-watts distributed as follows :—

For	Industrial purposes	12,000	kW
,,	Pumping for irrigation	15,000	,,
,,	Agricultural processes	3,000	,,
,,	Domestic and miscellaneous purposes	5,000	,,

The pumping load includes power for a system of 1,500 state tube-wells, each yielding 1·2 cusecs on the average, the Ramganga pumped Canal carrying 150 cusecs, the Kali Nadi feeder discharging 100 cusecs, a distributary fed from tube-wells carrying about 80 cusecs, and for about 300 private tube-wells. All these pumping installations command about 1·6 million acres. Power for agricultural processes is utilised in crushing sugarcane, hulling rice, cotton ginning, oil seed pressing and flour milling, all in rural areas. The total cost of the grid system is about 350 lacs of rupees, one-third of which represents the cost of generating stations. The primary object of the scheme is to help agriculture and develop rural areas. It has been subjected to a great deal of criticism on account of the unorthodox proportion of the length of the transmission system to the power installed. Recently one of the foremost scientific institutes of this country published a paper in which the writer opined that the rural transmission system should not have been constructed, and suggested that the electric installation on tube-wells might even now be replaced by oil engines. I may mention that the sale rate for power is nine pies per unit for irrigation pumping, and one anna per unit for other agricultural processes. The rates for industrial and domestic supplies compare very favourably with those of other electric supply concerns in the country.

The results of the last two years are a complete answer to the critics. In 1938-39 about 700,000 acres were irrigated. The peak load was 21,600 kilo-watts. 73·9 million units were sold which gave a yearly load factor of 39 per cent. The average sale rate per unit was 10·4 pies, and cost of generation and transmission per unit sold and delivered amounted to 7·44 pies. After deducting interest on capital, depreciation and working expenses, a net profit of Rs. 13·88 lacs accrued to the State.

During the current year the peak load has risen to 24,000 kilo-watts and the load factor is likely to rise to 45 per cent. The rate for tube-well pumping has recently been reduced to 8 pies per unit and is likely to be reduced further with increased load factor.

15. Full advantage has not yet been taken of the supply of electricity in about 2,000 villages. Owing to climatic reasons a considerable portion of the power reserved for pumping is available for the development of cottage industries in rural areas, during fairly long periods, when agricultural operations and demand for irrigation are slack. The cultivator can then utilise his spare time in suitable minor industries and suppliment his meagre income. The grid can afford to sell such power at nominal rates to the advantage of both the State and the cultivator.

16. Gentlemen, I have attempted to place before you my views on the necessity of devoting your attention to some problems, the chief of which is developing cheap water power. I have also indicated the various purposes for which this power can be used for the benefit of the industrialist and the cultivator, besides providing amenities for making life in this country more pleasant than it is at present. A satisfactory advance in civilization needs a balanced progress both in agriculture and in industry. It seems to me that little further progress in any of them is possible without cheap power. Its provision demands serious attention of the State, the capitalist, and the engineer. I am confident that the engineer will contribute his full share in his best professional spirit to the solution of this all important problem.

THE TWENTIETH ANNUAL DINNER.

The Twentieth Annual Dinner was held at Nedou's Hotel; Lahore, on Saturday, the 13th January 1940.

Khan Bahadur M. Abdul Aziz, C.I.E., the President of the Institution presided. His Excellency Sir Henry Craik, Bart., K.C.I.E., Governor of the Punjab, honoured the Institution with his presence as the Chief Guest. The other guests included the Hon'ble Mr. Manohar Lal, Mr. H. S. Bigsby. The Hon'ble Mr. Justice M.V. Bhide, Mr. B.F. Chritchley, Mr. E.O. Cox, Mr. G.C. Garbett, Col. C.F. Carson, Mr. E.B.N. Taylor and Mr. P. Bence Jones.

His Excellency the Governor of the Punjab proposed the Toast of His Majesty the King Emperor which was duly honoured.

The President in proposing the toast of His Excellency the Governor of the Punjab said:

Your Excellency,

It is my most pleasant duty, on behalf of the Institution of Engineers, to extend to your Excellency our hearty welcome and to express our deep gratitude to you for doing us the honour of attending our Annual Dinner.

When I was informed that the honour of proposing the toast of His Excellency the Governor of the Punjab, devolved on me, the story of a Company Commander, I had heard long ago, at once came to my mind. The Company Commander had been ordered by his Staff Officer in the last Great War to advance and retake a certain position, which had been lost. He heard and hesitated for a moment, then turned round to the Staff Officer and said: "I shall do my best but you know I am not a real soldier, I am only an ironmonger." This accurately

describes my position—Sir, as I am not an orator, and like the ironmonger am merely a workman. However, I will also do my proverbial "best".

This Province, over the destinies of which your Excellency presides, has always been in the forefront so far as Engineering activities in India are concerned. It is particularly so in the field of Irrigation Engineering, and I believe I am not far wrong in saying that your Excellency's Government mainly depends for its revenues on the efforts of its Irrigation Engineers who have constructed and worked with remarkable efficiency, a system of Canals unrivalled in the world. The Head of such an administration must naturally be greatly interested in all kinds of Engineering problems concerning this land of five rivers. A recent evidence of Your Excellency's interest in Irrigation works is the commencing of the Thal Canal scheme, a project, the execution of which has long been overdue, and in which incidentally, I am personally interested. Another instance is the encouragement you have given to schemes for the improvement of the Suburbs and the City of Lahore, which is reputed to be your first love. Lahore happens to be my birthplace and the home of my family. Though, unlike you, Sir, I have never lived here except for short periods occasionally, yet the love of this place is a sentiment I share with your Excellency. The starting of such schemes, in spite of the difficult international situation of the world, is a very strong testimony to Your Excellency's keen desire to further advance the achievements of this Province in Engineering which are already remarkable.

The progress must naturally be retarded, especially in a Province, which has to bear by far the heaviest part of India's share in the conduct of the War. War is a regrettable and necessary evil which must hold up if not actually set back many beneficial works. Though I am conscious of the not inconsiderable part, which the fraternity of Engineers has played, in making wars more gruesome, longer and tedious, and in robbing them of their spectacular features, yet from our point of view, some consolation lies in the impetus they give to the progress of Engineering developements and inventions, which are of immense value in times of peace. Let us hope that the combined efforts of our great Commonwealth of nations and its Allies will soon bring the present War to a

successful conclusion, when your Excellency's Government will be able to add to its laurels by taking up other large and beneficial Engineering schemes like the "Bakra Dam".

I now ask you Gentlemen, to rise and drink to the Health of His Excellency Sir Henry Craik, The Governor of the Punjab.

His Excellency the Governor of the Punjab in reply said:

Gentlemen,

Let me begin by thanking you for your genial hospitality and for the kind way in which you have responded to this toast. I need hardly say how pleased we are that you have this year elected to hold your annual dinner in Lahore, and that the occasion should be marked by your having a distinguished Punjabi as your President. While we regret that the Khan Bahadur's professional skill should not have been available for the benefit of his own Province, we can take pride in the thought that, like so many Punjabis who sought a career in other parts of the world, he has risen to the highest post of his service in the land of his adoption.

I was reading a book the other day by a scientist in which he proclaimed with pride "This is the age of the engineers. The pen may be mightier than the sword ; but the spark-gap is mightier than the pen." However, he had to admit that engineers did not have it all their own way, for a little further on he wrote "Lack of scientific education is the hall-mark of the successful politician." To this propostion I can off-hand think of only two possible exceptions. The first—and a very doubtful one—is Sir Stafford Cripps who, I am told, had some sort of scientific education ; for, although a politician, I am not sure that the political party to which he used to belong would admit that he is a successful one. The second, a much clearer exception, is no less a person than the celebrated M. Molotov who, I understand, began life as an engineer. He may perhaps be accounted a successful politician, though I do not think many of us would envy him for his recent achievements. In all the circumstances it is with feelings of satisfaction rather than of shame that I assure you, gentlemen, the members of my Government are *not* exceptions to the general rule ; though successful politicians all of them are quite innocent of scientific or engineering knowledge ; and what I myself add to the common stock

of ignorance is a minus quantity. We have, however, at our disposal to advise us no less than five Chief Engineers and in view of the fact that whenever they meet there is a sound of many voices, I cannot help thinking that it is perhaps fortunate that neither I nor my Ministers are encouraged by some smattering of technical knowledge to add to the babel.

Gentlemen, the Punjáb is proud and I think justly proud of its engineering achievements and traditions. We realise that such prosperity as we have so far enjoyed is largely due to our engineers and that our hopes of future development depend mainly on their skill. In every field of our economic life we are dependent on their inventive genius and their watchful care. Our roads, our railways, our canals, our electric power for the industries, which are now springing up in this Province, the modern drainage and water supply of our great cities : all are the work of their hands. With this vast field there is more than enough to keep occupied our engineering talent even in time of peace, and now the demands of the war are likely to make a further heavy call on it. Persons with engineering qualifications are required by the Central Government not only for Defence Services, to which our technical services have already made a notable contribution, but also for the engineering industry to which war has already given a decided impetus. Nevertheless we are still hoping to carry on with our peace time programme, and though, I believe, some of the machinery designed for the Thal Project is at present lying somewhere at the bottom of the sea, we have not yet abandoned or even postponed this the last of our great weir irrigation projects, though we may be forced to slow down the pace of its construction.

On such an occasion it would not be fair to detain you with a complete survey of the various engineering activities at present in progress in this province ; but I think before I sit down I ought to let you know what you may not yourselves have realised—that you are staying in a city which has on the one hand been described as the dirtiest capital in India and on the other been heralded as the paradise of the future. This enviable status which awaits Lahore is all attributable to gentlemen of your profession, who are enagaged in banishing its worst smells by means of a new system of drainage. Into this more fragrant paradise we hope to conduct you when you next honour us by meeting here.

When such are the benefits which engineers confer you can well imagine, gentlemen, how much we in the Punjab value your Institution, which is designed both to promote the development of engineering in India and to ensure that the highest standards of your great profession are maintained.

Rai Bahadur B. P. Varma in proposing the toast of Our Guests said:

Your Excellency, Mr. President, Ladies and Gentlemen,

In the turmoil of technicalities and of other important business of the Institution with which I was and will be occupied during the next few days, my pleasant task to-night comes as a welcome interlude. It is no other than drinking with my fellow members of the Institution to the Health, Long Life and Prosperity of our distinguished guests.

The Institution is a self-governing body. It has created a number of self-governing centres spread out in the various Provinces. These Local centres as well as the Mother Institution conduct their affairs under the rules contained in the "Royal Charter". We owe allegiance to none except to our own members.

Our Institution here in Lahore feels honoured by the presence of its guests, extends to them the right hand of Fellowship, the Fellowship of co-workers for the good of mankind and for the peace and prosperity of the world. I on my part wish to thank them for their kindness to be with us this evening, and to extend a hearty welcome to them all. To those who live in the Punjab their names are household words and I will not specify their names. But for the benefit of those of our members who have come from other Provinces, I may mention that we have with us to-night, distinguished guests, representing the various departments, such as Administration, Finance, Irrigation, Commerce, Communications and Railways. It is needless for me to state that the peace and prosperity of this great and important Province of India lies in their hands. To the representatives of the Press I accord a special hearty welcome. They are a powerful body and can do a lot of good within their sphere of influence by well directed and constructive criticism. The Engineers also need their help in the matter of advertisement and enjoying criticism of the constructive variety.

The shadow of a Great War frowns upon us, though at present, from a distance. Scarcity of rains and a famine we feel are near at hand, but as Engineers we can certainly help to keep the peace—and just with the same certainty to be able to help towards bringing in prosperity in this Country. It is a well-known fact that Engineers are not concerned with castes, creeds or national distinctions, but only with the harnessing of great resources of Nature for the benefit and service of mankind. Our work is usually creative and in a few cases preventive. In either case it is beneficial to mankind. As an example the solution of India's difficult situation lies chiefly in the development of her industries and by the help which we can render in this development, we ought to be doing our "little bit" towards the cause of peace and contentment, by keeping down unemployment and crime.

Now-a-days the Engineers and his works are getting more and more intimately connected with those who labour in the realms of science and also with those who are in the pursuits of Commerce, Finance and Politics. Thus the sphere in which Engineers can render themselves more and more useful to their fellow beings has become simply unbounded.

The Engineers as a rule are silent workers for they lack the necessary eloquence for advertising their usefulness. They are "men of works and not of words".

Gentlemen, now I will tell you on old story. A cynical Philosopher of times gone by said that there were only three things in life which were difficult of attainment.

1. Being Poor to obtain Justice.
2. Being Rich to escape Flattery.
3. Being Human to avoid Passions.

Gentlemen, it is true that you are not concerned with any of these to-night, but a Philosopher, if we can find one in this age can very well tell you of a fourth and much more difficult to attain than the other three things mentioned above, it is "Being Civilised to escape the Engineer".

I now ask the members of the Institution to rise and drink with me the Health of Our Guests, both in their proper persons and representative capacities, coupled with the name of The Hon'ble Mr. Monohar Lal.

The Hon'ble Mr. Monohar Lal in replying to the toast eulogised the work of the Engineers in this country and the part played by the Institution in bringing them together for further deliberations over engineering and scientific problems for the betterment of the country in general and the advancement of the profession in particular.

Mr. H. S. Bigsby proposed the toast of the Institution in reply to which Khan Bahadur A. G. Khan said:

Your Excellency, Mr. President, Ladies and Gentlemen,

On behalf of the Institution of Engineers (India), it is my privilege to thank you all for the cordial way in which the toast of "The Institution" has been honoured and to say how grateful we, members of the Institution, are to Your Excellency, and to you, Mr. Monohar Lal and Mr. Bigsby, for the generous terms in which you have referred to the Institution and its activities.

Mr. Bigsby has told you an interesting story of how one of the greatest irrigation engineers in the Punjab used to allow himself to get heavily absorbed in the study of silt. Permit me to tell you another story—this time not about an irrigation engineer but about an engineering professor who was a great authority in the design of electrical machinery. One day he was absorbed in the solution of a knotty problem. On that very day his wife was to meet him at the University, have tea with him and go together to the Pictures. She turned up at the appointed time—only to be told to wait for a few seconds in the waiting room. After a few minutes, the learned professor put on his coat and hat, proceeded to the tea room and after taking his tea returned alone to his house. The lady returned home in great disappointment but was greatly amused to find that his stick was lying on the seat on which he used to sit and in the corner where his stick used to stay, he himself was standing still heavily involved in the study of the problem!

The Hon'ble Mr. Monohar Lal has invited your attention to the advantages that must accrue from the development of industries. Mr. Bigsby has referred to the problems of silt and waterlogging that are still awaiting solution. Both have left to me to tell the visitor to this great province that irrigation and other engineers are gradually turning the Punjab of scattered agriculturists into a prosperous and compact unit of increased and scientific production, delivering the people from the

consuming losses of chance by giving them the science of controlled and directed effort. Their vast irrigation projects, ranking among the greatest achievements of the engineer in India, are making the greatest material contribution to the prosperity of the province. Their spectacular hydro-electric scheme, easily the most daring engineering enterprise in India—I would not say the most expensive—is opening an era of great expansion in the electrification of the province. Their extensive road and rail systems with well equipped large railway workshops are loudly proclaiming that time and distance shall no longer stand in the rapid growth of agriculture, commerce and industry of this great province. Their textile industry, both cottage and mechanized, is gradually gaining ground to become an important asset in the prosperity of the people. Their cottage industries are fast developing to become valuable adjuncts to agriculture. Even their mechanized engineering industry—a remarkable achievement for a province essentially agricultural—is rapidly developing and, in several important lines, as for instance, manufacture of electric fans, electric blowers, small electric motors and switchgear, manufacture of paints and varnishes and pumps and strainers, fabrication of bakelite products, electric steel castings, manufacture of heavy oil engines and railway carriage fittings, fabrication of steel doors and windows, manufacture of Vacuum Brake and other India Rubber fittings for Railways and manufacture of a most important railway carriage component, namely, the axle box, their province has already become a worthy competitor of Bengal and Bombay. I have no hesitation in saying that even in advanced branches of engineering industry, as for instance the manufacture of heavy oil engines, the Punjabi machinists and mechanics are displaying, even as amateurs, technical skill and resourcefulness which is highly creditable. With necessary guidance and assistance, tremendous possibilities in engineering developments are in store for the province in the coming years.

As this is the first occasion that the Institution is holding its annual session in this province, I may be permitted to say a few things about its genesis and evolution. The question relating to the genesis is linked with the question of engineering progress. Scientific methods take a long time to develop. The beginning of scientific institutions lies with the formation in Great Britain of the Royal Society in 1660. Then we had

the Royal Institution of Great Britain in 1800 and later the British Institution of Civil Engineers, then, in 1847, the British Institution of Mechanical Engineers and finally, in 1871, the British Society of Telegraph Engineers which later developed into the British Institution of Electrical Engineers.

The value of the Engineer began to be appreciated in India particularly during the last Great War. It was realised that the Engineer in post-war India was bound to play a great and worthy part. He was to carry out, with irrigation, road, rail, hydro-electric and various other engineering projects, a constructive transformation in this country, battling for victory over the unregulated forces of nature. It will be the Engineer in India on whose labours will become daily more dependent not only industry and commerce but also agriculture, the mainstay of this country.

Impressed by the practical achievements in Great Britain of the three great British Engineering Institutions and convinced of the great role which Engineers had to play in India, it became apparent that the first and the most important step to help Engineers and Engineering in this country was the organization of engineers into a corporate body, which would lay down and enforce standards relating to the education and practical training of engineering students and the qualifications and conduct of engineers and which would promote and advance the science, practice and business of engineering in all its branches.

Such an organization was brought into being in this country in 1919. It is our Institution, the Institution of Engineers (India).

Inspired by Sir Thomas Holland, modelled on the lines of the British Institutions, inaugurated by His Excellency Lord Chelmsford, developed by a band of eminent engineers, British and Indian, recognized by the Government of India, the provincial Governments and their public services commissions, and, having been assured of its usefulness to Engineers and Engineering in India, Royal Chartered by His Majesty the King Emperor ; such are the credentials of the Institution, the 20th Anniversary of which is being celebrated here this evening. A further testimony to its usefulness is the fact that although it took no less than 50 years for the British Institution of Electrical Engineers and as long as 83 years for the British Institution of Mechanical Engineers to be incorporated by Royal

Charter, the Institution of Engineers (India) rose to this dignity in a short period of only 15 years. The special feature of this Institution is its representative character. It embraces the whole of India and all branches of engineering. Virtually, it is a Commonwealth of engineering interests covering all sects and creeds in engineering.

Sir Joseph Bhore, when Member-in-Charge of the Government of India, Department of Industries and Labour, summed up the authority of the Institution in engineering matters in the following words :—

"The Institution has now definitely established itself as the acknowledged authority of sound engineering tradations. The Government of India have given practical proofs of the estimation in which they hold it and its work." This in brief is the genesis and evolution of the Institution.

I shall not deal here with its statistics. I will rest content by saying that it has to-day no less than seven local centres and its membership, a very rigidly controlled privilege, has risen from 129 in 1921 to about 1,500 in 1939. It could well have been 15,000 but for the insistence, and rightly, on the rigid maintenance of the high standards laid down by the Institution, the importance of which cannot be exaggerated and which has placed the Institution on equal footing with the parent Institutions in Great Britain.

There are no less than eleven objects and purposes laid down in the Royal Charter for which the Institution was constituted. I would refer here specifically to three directions in which the work of the Institution will prove of great value to India and particularly the Punjab :—

Firstly, insistence on the maintenance of specific standards relating to the training in theory and practice in engineering for graduates who desire to become eligible for being classed as Chartered Engineers and rigid maintenance of such standards. A recent example of the work in this direction was the recognition of the B Sc. Engineering degree of the Punjab University, and of Class A diploma of the Maclagan College of Engineering, Moghalpura, now called the Punjab College of Engineering and Technology, a name which may have to be changed again as several more such colleges are bound to grow up to meet the expanding needs of this province. These recognitions and the

fact that the Punjab might easily become the foremost province in India for the excellence of facilities for practical training in all branches of engineering should add considerably to the sphere of usefulness of the Punjab University not only for the Punjab but also for areas far beyond.

Secondly, work connected with the re-orientation of the engineering curricula of Indian Universities to suit modern conditions and special requirements of India. A strong sub-committee is now busy examining this important question.

Thirdly, work, contemplated, connected with the establishment of engineering standards for India, similar to those formulated by the Engineering Standards Association in Great Britain and the Engineering Standards Association in Canada, intended to assist the buyer to purchase efficiently consistent with economy and to help the indigenous industry to work to well-defined standards compatible with planned economy. Engineering industry in the Punjab, both cottage and mechanized, which is rapidly growing, is bound to benefit considerably from the fruits of such labours of the Institution.

In conclusion, I should like again to convey our thanks for the way the toast of "The Institution" has been honoured and to express the hope that this Institution may continue to receive your good wishes and support in consolidating the position it has already won and in extending its usefulness to Engineers and Engineering in India, particularly in the Punjab.

ADDRESSES OF CHAIRMEN OF LOCAL CENTRES

Address delivered by Mr. S. C. Majumdar. B.Sc. (Glas.), M.I.E. (Ind.) at the Nineteenth Annual General Meeting of the Bengal Centre on 12th December, 1939.

Gentlemen,

My first duty is to thank the members of the Committee of the Bengal Centre for having elected me as their Chairman for the ensuing year. I confess that, owing to pressure of work, I have not been able hitherto to devote as much time to the Committee's work as I could desire and I am all the more grateful that inspite of my shortcomings you have conferred on me this great honour. My distinguished predecessor who is just vacating office, apart from his undoubted abilities, had an additional advantage in his favour. Having retired from service he could devote sufficient time and energy to the Committee's work. Though I may not be able to spare as much time I shall try to discharge the duties to the best of my abilities and trust that with your co-operation we shall get along.

2. Following the precedents established by my predecessors I find that I have to say something on this occasion. Being an Irrigation Engineer and having to deal with rivers on which depend the health and wealth of Bengal, I can do no better than present you with some of our problems with an indication as to the measures that I consider necessary to solve them. This will not only be in keeping with the ideal of this Institution which is to promote healthy discussion on important engineering problems with a view to advancing our knowledge on the subject but, incidentally, it will also enable me to ascertain the views of independent technical experts which will be so helpful to me in the discharge of my official duties.

3. As you are aware the major portion of this Province is deltaic having been built up by the silt carried by her magnificent river systems. In fact, it can be truly said of Bengal that the rivers created the land, they have been draining and fertilizing it and helping in the transportation of the produce of the country. Where the rivers are healthy and still in a position to continue these beneficent activities the country is healthy and prosperous. But in large areas in Western, Central and Northern Bengal, partly due to human interference with the natural deltaic action and partly due to changes in their courses, the rivers have deteriorated and are no longer able efficiently to drain the land nor to fertilize it by their silt-laden flood spill. In consequence there is progressive deterioration in public health and in the productivity of the soil. I shall not attempt this evening to make a comprehensive review of the various complicated river problems in Bengal but shall confine my remarks to some of them with which we in Calcutta are very much interested *viz :* the problems presented by the tidal channels of Central Bengal with special reference to the Bidyadhari river on which this second city within the empire is dependent for the disposal of its drainage.

4. Most of these tidal channels really constitute the outfalls of the spill channels from the Ganges and before the diversion of the Ganges towards the east, they used to receive a copious flow of upland water and were in vigorous condition. Even after the diversion of the Ganges and consequent curtailment and, in some cases, stoppage of the upland water supply, they continued to maintain themselves with the help of their spill areas and except where free tidal flushing of these spill areas has been interfered with by premature reclamation by means of marginal embankments they are at least able to discharge their primary functions of drainage. In many cases they are also in sufficiently good condition for purpose of navigation—a valued natural asset which should be preserved at all cost. Mere tidal flow, unless reinforced by supply of upland water, cannot, however, maintain any channel for an indefinite period. Tides in these parts carry a large proportion of silt with which nature is trying to raise the lower portion of the delta now deserted by the Ganges floods. It is only a question of time when the spill areas having been raised up to tide level, this silt, unable to spread

over the land, will deposit in the channel bed in larger and larger quantities and will finally choke it. A gutter channel will probably remain for draining the local rainfall but the channel will no longer be fit for navigation. Besides, with the reduction of pressure of sweet water from above, the salt water limit is also being pushed up these channels, and a serious situation is likely to arise if the upper reaches of these channels continue to deteriorate and the supply of sweet water is further reduced. In fact, it appears that the salinity of the Hooghly water near Calcutta, on which this big city is dependent for its water-supply, is showing a tendency to increase during the dry season. The case is probably similar or perhaps worse with regard to the tidal portion of the other spill channels in Central Bengal, as the only source of sweet water for these channels is the Ganges and from December till June they remain entirely cut off from this source, except the very small supply that is drawn by percolation through the sandy beds at their off-takes.

5. But where free tidal flushing has been interfered with by premature reclamation of spill areas by means of marginal embankments, the situation has already become serious, and at several places owing to the deterioration of the tidal channels the difficulties of drainage are becoming more and more acute. Apart from serving as carriers of country drainage with which we are all familiar, these rivers of Bengal both upland flood carriers as also the tidal channels, perform the most important function of raising the delta we live in. Owing to the diversion of the Ganges the upland flood carriers are no longer functioning in Central Bengal, and so tidal channels are the only agencies now left by which the lower portion of Bengal could be raised and made fit for human habitation. Another point to be noted is that when the upland flood carrier dies in a particular area, as for instance in Central Bengal, though that area suffers, its beneficent activities are not lost to the country ; only these are transferred elsewhere. If, however, a tidal channel is obstructed it usually gets choked in its own bed without any chance of diversion by avulsion as the energy required for the purpose is lacking, it not being possible for a tidal channel to rise above the tide level. Thus the consequence of premature reclamation by marginal embankments or other obstructions in tidal channels is that their beneficent activities of raising this portion of the delta will be lost to the country for ever and the land will

continue to remain low with increasing difficulties of drainage until it becomes unfit for human habitation and reverts to swamps and jungles. We have instances of this almost next door to Calcutta, *viz.*, the low areas served by the Bidyadhari which, owing to earlier reclamation of the spill areas, is now completely dead and can no longer serve as a carrier of drainage, with serious consequences to the city of Calcutta and suburban areas. The Peali is also fast dying and will probably share the same fate as that of the Bidyadhari unless steps are immediately taken to throw open sufficient spill areas for this river. The provision of spill areas by the removal of marginal embankments seems to be an urgent necessity for prolonging the life of these tidal channels. But this is not enough. If these channels have to be given a permanent lease of life the supply of upland water seems to be an essential requirement. As this point is not usually understood it seems necessary to explain the physical characteristics of tidal rivers.

6. The energy which creates the tidal flow, *viz.*, the attraction of the sun and the moon in the sea is very limited and is manifested partly as potential energy, *viz.*, rise in tidal level, and partly as kinetic energy, *viz.*, velocity of flow. The former causes the tidal flow up the rivers and the latter determines its power of transporting silt. As the velocity of the tide when it enters the mouths of these tidal rivers is high and as there is a vast reservoir of unconsolidated silt in suspension along the delta face, the tide as it flows up these rivers is highly charged with silt. It is generally observed that the duration of ebb tide in a tidal river is much longer than that of the flow tide. As the same quantity of water must ebb out as flowed in, it, therefore, follows that the average velocity of 'ebb' is less than that of 'flow'. Now the capacity of water to transport silt depends on its velocity. Consequently the ebb tide is generally unable to carry back all the silt that has been carried up these tidal rivers by the 'flow tide'. Even a slight deposition of silt will add to the accumulation as the tides function twice daily throughout the year and the channel will begin to deteriorate. The deterioration would impede the propagation of the tidal wave which would cause further deterioration and the vicious circle would continue till the channel is completely dead.

7. It will, therefore, appear that to maintain the life of a tidal river what is necessary is an additional supply of water not saturated with silt, *i.e.*, which has the reserve capacity to pick up more silt, to supplement the tidal flow during ebb so as to scour out fully the silt that has been admitted into the river by the flood tide. This could be effected either by the supply of upland water, local drainage, or by throwing the existing spill area open to the daily ebb and flow or by adding new spill areas, if possible. The spill area is of course an important flushing agent but it would function only for a limited period at a gradually diminishing rate, till the whole area is raised to high water level and its storage capacity is reduced to nil. The local drainage would also be helpful specially while crops are standing in the fields, as the water at such time would be practically silt-free. But this agency can function only during the rains, and for 7 months (November to May) no material contribution can be expected from local drainage, however large the drainage area may be, to help in flushing the river during ebb. The third agent, *viz.*, upland water, is certainly the most important and if it were possible to arrange for its supply perennially, so as to flush the river even during the dry season, there is no reason why a tidal river should not live and continue her beneficent activities for a great length of time.

8. In recent years the Bidyadhari river has been very much in the public eye owing to the increasing difficulty that is being experienced in disposing of the drainage from Calcutta through this outfall. I, therefore, propose to take up this river as a typical representative of this group and briefly review its life history to illustrate these points. It may be mentioned that before the diversion of the Ganges flood through the Padma, the Jamuna constituted one of the main branches of the Ganges. Separated off at Tribeni the flood used to flow down this stream to the sea. In fact, between the Bhairab and its branches to the east and the Hooghly river to the west, the Jamuna was perhaps the most important delta builder in those days, and largely contributed to the raising of this portion of the Sunderbans. The Bidyadhari was an important spill channel of the Jamuna and to her was allotted the task of raising the delta just to the east of the areas near about Calcutta. Channels connecting the Bidyadhari with the

Jamuna in the olden days (Nowi, Sunti and Nanagong) can still be traced reaching within a few miles of the present abandoned course of the Jamuna.

9. But the most indisputable evidence that the Bidyadhari used to receive a considerable supply of upland floods is afforded by the width[1] between the high banks of what is now called the Bidyadhari *khal* just above Bhangore canal. In fact I was surprised to find such high natural banks in the midst of what was known to be a purely tidal area when I inspected the *khal* in 1933. I had several cross sections taken to ascertain whether they were really above the high tide level as that would prove conclusively that the Bidyadhari used to receive upland floods. As the cross sections show, these banks are much above the high tide level even of the present day (which must be considerably higher than when the river was allowed to spill freely over the banks), and they could not have been built up by the tidal silt but must have been raised by the silt carried by the upland water. Having regard to the characteristics of delta builders of which the banks slope away from the river edge, the width between the crests of these high banks, therefore, gives a rough measure of the extent of upland flood supply in the olden days and, judged by this standard, it must have been considerable.

10. I would particularly emphasise the importance of this method of reconstruction of the life-history of deltaic rivers by means of cross sections. After completion of the contour survey of Central Bengal, portions of which have already been surveyed, we should have a lot of data to help us in this direction. For instance, from cross sections of the country round about the Saraswati I found that this river, which now looks like a gutter, was originally a big river, thus corroborating the view that the Saraswati was a branch of the main Ganges as there is no other delta builder on this side of the country which could throw a branch of this size.

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[1] The width varies from 350 ft. to 900 ft., the average being 660 ft. and the level of the bank from 10·21 to 16·66, the average being 12·57 ft. within a length of about 10 miles above Bhangore canal. As compared with this the highest tide level recorded at Bamanghata on the Bidyadhari, which is progressively rising, was 10·33 and the average High Water 8·8 in 1932. At Haroa (a short distance above the length considered) the H.H.W. and the average H.W. level in 1932 were 11·0 ft. and 8·75 ft. respectively.

All levels referred to are taken on O.M.S.L. or P.W.D. datum.

11. By similar evidence left by nature it was also found that the Kultigong, which now constitutes the outfall of the Nowi, Sunti and Nanagong (formerly feeders of the Bidyadhari), probably opened up much later than the Bidyadhari. In any case it was originally a channel of minor importance as compared with the Bidyadhari. Measured from the present outfall of the Nanagong into the Haroagong (the connecting channel between the Kulti and the Bidyadhari) high banks much above the high tide level extend to only a little over 6 miles along the Kulti route, while along the Bidyadhari they extend to at least 14 miles. I have discussed these points at length in my official report on the "Bidyadhari Restoration Scheme" and it will unduly lengthen this address if these evidence and arguments are reproduced here. I shall merely summarise the conclusion that I arrived at after a critical analysis of all the available evidence.

12. So long as the Jamuna remained active the Bidyadhari used to get a considerable supply of upland water (including a portion of the dry weather flow of the Ganges), not only the flood carried by the Nowi and Sunti, but also the major portion of the flood carried by the Nanagong. Deterioration of the Jamuna probably set in soon after the diversion of the main volume of the Ganges flood towards the end of the 15th Century or early in the 16th Century. It seems probable, however, that it still continued to receive, at least during the rains, a share of the Damodar flood, which had one of its outfalls into the Hooghly near Kalna until about 1660 and near Noaserai until about the middle of the 18th Century, both the places being above the off-take of the Jamuna at Tribeni. Diversion of the Damodar down its present channel with its outfall below Uluberia at the latter date finally sealed the fate of the Jamuna which, together with the spill channels, began to deteriorate rapidly.

13. Deprived of the upland water supply, the Bidyadhari was then thrown entirely on her own resources, *viz.*, local drainage and spill area to prolong her life as long as she could. At this stage another characteristic, peculiar to tidal rivers carrying a large proportion of silt, hastened her decay. The Kultigong, the next parallel tidal channel to the east, had already opened up and by means of the connecting channel, now known as the Haroagong, provided a meeting ground for

tides coming up both this river and the Bidyadhari. Owing to check in velocity there is always a heavy deposition of silt at the tidal meeting ground, but so long as these rivers received a plentiful supply of upland floods, this silt could be cleared by flushing during floods. After the stoppage of this supply, the silt deposited as a result of the meeting of the tides became a grave menace to the preservation of both the channels. Nature had thus to sacrifice one for the preservation of the other. It seems to me that by this time the Kultigong, which was originally discharging into the Matla through Kumerjolgong, had her present outfall into the Roymangal Estuary definitely established. Now the Roymangal is one of the deepest estuaries in the delta and the conditions for the propagation of the tidal wave being more favourable, the stronger tide up the Kultigong could travel higher and higher up the connecting channel (Haroagong), thus shifting the tidal meeting ground more and more down the Bidyadhari. The Nanagong, the Sunti and the Nowi, which originally used to feed the Bidyadhari, were thus gradually absorbed by the Kultigong for her own sustenance. By robbing the Bidyadhari of the drainage and spill areas of these feeders, the Kultigong thus began to develop at the expense of the Bidyadhari and the latter river deteriorated rapidly.

14. But though the fate of the Bidyadhari as a permanent channel was thus sealed, the existence of a large spill area in the salt lakes should have made it possible for her to function as an outfall for the drainage from Calcutta and the neighbouring areas for a much longer period but for the acts of man. The salt lakes, even after reclamation along the borders now measure about 55 sq. miles and, it seems to me, define the boundary between the area built up from the north by the upland floods and that from the south by the tides carried up the Bidyadhari and the Peali. Even after the stoppage of upland floods it should have been possible for nature, but for human interference, to raise this area by tidal deposit instead of leaving it as a nuisance so close to the city.

15. The first interference was the premature reclamation of the land on either bank of the Matla and of the Bidyadhari by means of marginal embankments, towards the middle of the last century. This was one of the earliest areas to be reclaimed,

and consequently both the channels began to deteriorate with progressive rise in tide level or what may be called "heaping up of tides". At Port Canning (Bidyadhari outfall into the Matla) the highest high water level has risen from 6·28 in 1865 to 12·83 in 1930 (O.M.S.L. data). At Dhappa the ordinary high water level in 1830, as gathered from old records, was 1·5 in the dry season and 3·5 in the rains. The H.W. level was 9·41 in 1926. At Bamanghata on the Bidyadhari the H.H.W. level has risen from 9·1 in 1894 to 11·00 in 1926. It will be of no use referring to the level at Dhappa and Bamanghata in recent years as tidal flow is practically non-existent and the level is really ruled by the discharge of Calcutta drainage, but it may be noted that the present level is considerably higher. The Bidyadhari, which hitherto used to drain Calcutta, is now trying to drown the city with the sewage and we are trying to prevent the catastrophe by means of flood embankments proposed to be constructed along the eastern boundary.

16. Now this "heaping up of tides", which occurs when a tidal wave is unable to dissipate itself over the spill area, is another characteristic of tidal rivers, and where tides carry a long proportion of silt, as in Bengal, it causes deterioration of the channel by the dropping of silt. The explanation is probably as follows: "Heaping up" of tidal flow really means gain in potential energy. But as the sum total of the energy generates this flow, *viz.*, tidal impulse created in the deep sea by the attraction of the sun and the moon, etc. is constant during each tide, this gain in potential energy must be attended with a corresponding loss in its kinetic energy, or in other words the flood tide can only rise in level at the expense of its velocity. Now the silt-carrying capacity of the flow being proportional to the velocity, it follows that as soon as "heaping up" occurs a portion of the silt brought up by the tides, in excess of what the reduced velocity can carry, drops on the bed, thereby further impeding the tidal wave and accelerating the deterioration of the channel in a vicious circle. This phenomenon of "heaping up of tides" is going on more or less in almost all the tidal rivers, where the spill area has been unduly curtailed and really constitutes the preliminary warning of deterioration. In the Bidyadhari, and at the head of the Matla Estuary, the "heaping up of the tides" is probably the worst as their spill areas have been the earliest to be reclaimed. It becomes less and less as we move towards the eastern parts of the delta.

17. The second stage of human interference was the discharge of the Calcutta sewage into the Bidyadhari. While the liquid content has probably been helpful, especially during the dry season, the solid matter has certainly been harmful specially by forming a gelatinous coating over the channel bed and slope which the ebb flow finds it difficult to scour. The large number of fisheries in the salt lakes and other low areas also contributed to the deterioration of the Bidyadhari by preventing free tidal spill. Finally, the Kristopur canal by interfering with the natural drainage from the north, accelerated the death of the Bidyadhari.

18. Attempts were made to revive the Bidyadhari both by acquiring a spill area (about $2\frac{1}{2}$ sq. miles which was found to be much too small) and also by dredging at a heavy cost. But the opposing forces were found to be much too strong and the Bidyadhari continued to deteriorate. She is now absolutely dead without any chance of revival and it would be interesting to note the rapid rate of deterioration from the following figures :—

	1883.	1904.	1936.
Lowest Bed level near Bamanghata referred to O.M.S.L. or P.W.D. datum	—58·69	—29·71	+ 5·75

The present bed is even higher than the country level on either side.

	1894.	1915.	1917.	1926.	1932.	1936.
L.L. water level at Bamanghata	—4·9	0·0	+0·17	+2·5	+5·92	+11·05

	1926.	1936.
Cross Sectional area at Bamanghata below R.L. 9·75 ..	2,440 sq. ft.	363 sq. ft.

19. All attempts at the restoration of the Bidyadhari have now been rightly abandoned and the Calcutta Corporation are dredging an independent outfall into the Kultigong. But the difficulties are not yet over. In the first place the Kultigong needs looking after. The death of the Bidyadhari has at least taught us one important lesson *viz.*, that we can no longer allow these valued natural gifts to die a premature death by following a policy of *lai-ssez-faire*. Apart from serving as

outfall for drainage from this large city the Kultigong is the only healthy channel now left in these parts for draining a large area in 24-Parganas District and constitutes the western approach to the important Boat Route to Eastern Bengal. Both the Governments as also the Calcutta Corporation should therefore be vitally interested in the question of preservation of the Kultigong. I am glad to be able to inform you that in this respect both these authorities have agreed to work in co-operation and necessary survey and investigation are in progress. In the absence of upland water supply we have naturally to depend on the local drainage and spill areas to prolong the life of the Kultigong. As local drainage will not be helpful except during the rains we have to depend mainly on the spill area and as this area (now fully embanked and will have to be acquired as necessity arises to serve as spill area) is limited in extent it is of utmost importance to use it economically. If the area that is thrown open to free spill at a time is much too large the Kultigong will develop requiring even larger area for its maintenance and the total area available, which is practically the only agency now left for maintenance of this river, will soon be exhausted. On the other hand if the area is less than what is required the channel will shrink and will no longer be able to discharge its present function of drainage and navigation. It is, therefore, very necessary to know the exact spill area that is required to preserve the Kultigong in its present condition. As there are so many indeterminate factors involved no reliable estimate is possible from theoretical consideration but the necessity for testing the proposal by means of a model is keenly felt. I have already submitted a proposal for establishing a River Research Institute for Bengal for testing this and various other proposals in connection with our complicated river problems and it is now under consideration of Government.

20. Secondly the death of the Bidyadhari has made it necessary to redistribute the drainage basins, which were drained by this river, between the Kultigong and the Peali. As the Corporation drainage channels from Calcutta have been aligned across the natural slope of the country it is no longer possible to drain the area lying to the north of these channels towards the south into the Peali and as the L.W. level of the Hooghly is usually very high during the monsoon drainage from this area has to be disposed of ultimately into the Kultigong.

Though this is a step in the right direction so far as the maintenance of the Kultigong is concerned it makes the problem of maintaining the Peali more difficult. The Peali off from the Bidyadhari at Narayanpur and owing to meeting of tides near about this point, has been deteriorating for years though not so rapidly as the Bidyadhari. In 1933 when I examined these problems, though the Peali had deteriorated from Narayanpur to Uttarbhag, the lower reaches were found to be in fair condition. As the available resources *viz.*, the spill and drainage areas were found to be insufficient to maintain both the branches I thought that the prudent course was to sacrifice the weaker one *viz.*, the Bidyadhari which, it seemed to me, had reached a stage of deterioration beyond any reasonable chance of restoration and try to prolong the life of the Peali by placing at its disposal all these resources including drainage from Calcutta and the suburban areas and made my proposals accordingly. It will serve no useful purpose in reopening this controversy which is now past history but we have to face the situation as it now stands and see how best we can meet it. As I have mentioned before the drainage from the city of Calcutta and the area lying to the north of the Corporation Outfall Channels is no longer available for the sustenance of the Peali. It has also very rapidly deteriorated during the interval requiring improvement by dredging at least upto Dhose. But though the cost of improvement of this river will now be very much heavier for the purpose of draining the Southern Salt Lake and the large water logged areas to the east and south-east of Calcutta I see no alternative but to improve the Peali by dredging and to place at her disposal sufficient spill area for her maintenance in future. In fact the drainage congestion in these areas has been so acute in recent years that portions of Tollygunge Municipal area now remain flooded throughout the monsoon and my friend Mr. Ghosh, the Chief Engineer, Public Health Department and one of the past Chairmen of our Committee, is pushing through a scheme of isolating this urban area by means of flood embankment and draining it by pumping.

21. In conclusion I may mention that a scheme for improvement of the Tolly's Nalla has been sanctioned and we propose to start the work soon. This will no doubt offer some relief to the drainage congestion referred to above but as the

L.S. level of the Hooghly is usually very high during the flood season such relief is not likely to be very material till after August.

Address delivered by Mr. J. D. Daruvala, M.I.E. (Ind.), at the Eighteenth Annual General Meeting of the Bombay Centre on the 18th November, 1939.

I am deeply grateful to the Committee of the Local Centre of the Institution for the honour they have conferred upon me in electing me as Chairman for the ensuing year. I hope that it may be within my power to prove a worthy successor to those who have preceded me in this office and that I may be in a position to assist and advance the prestige and value of the Institution in the Engineering World. I fully realise that the task on which I have been asked to set my hand to-day is not an easy one as I have a high standard to follow set by those who have held this office before me, and it is due to their endeavours that the prestige of the Institution stands so high to-day, and I can only assure you that I will do my best.

Ever since the grant of The Royal Charter the members of your Committee of the Local Centre and your members of the Council have spared no pains to see that the high standard of admission is the more so maintained and that applications for corporate membership of this Institution are still more carefully scrutinised so that the attainment of its membership might convey to all that the same is a hall-mark for an Engineer. The Institution occupies an important position representing as it does many eminent engineers, Civil, Mechanical and Electrical in this country and abroad, who are engaged in works that are advancing the engineering science to meet the needs of mankind. These needs are ever increasing and altering with the progress of civilisation and mankind.

Whilst I do not propose for one moment that we should enlist on our roll persons who do not satisfy the requirements of our bye-laws as members of our Institution, I do firmly believe and think that there are eminent engineers in the various branches of our profession in the area within the jurisdiction of this Local Centre, who have not so far applied for membership, and to them through you I make a special appeal to-day

that they should join us so that the more representative the character of membership of our Institution the greater will be its worth in questions concerning our profession in general and the status of engineers in particular.

A perusal of the annual report which is now in your hands would reveal to you that during the last year our Local Centre had taken up several important questions with the Provincial Government and local bodies in this province, and if a correct prestige and worth is to be carried by any Institution, it can be only so done if its membership is not only large but representative and selected.

The question of Registration of Engineers in India was discussed at the last Annual General Meeting of the Institution held at Benares and the considered opinions of the different centres were discussed. The draft bill was discussed by the members and the same was referred to the Council for more detailed examination and report. The Council of the Institution in persuance of this resolution of the General Body referred this matter to a small Sub-committee to go through the draft bill and submit their report on the same. The sub-committee have already submitted to the Council a very exhaustive report on the question of Registration of Engineers in India and they have suggested that a start may be made by moving the Provincial Governments to enact suitable legislation for the Registration of Engineers in provinces where the majority of members are in favour of such legislation. Their recommendation is borne out by the provisions of the Government of India Act of 1935 regarding such legislation in respect of the legal, medical and other professions.

Reference to the Government of India Act makes it clear that such a legislation should not necessarily be a subject of the Federal Legislature. You will agree with me that it will be advisable to make an early start with the question of registration of engineers in this country and I believe it would be seen to if the matter is first tackled in the provinces. If at a later date it is found necessary to have an all-India legislation to co-ordinate the legislations enacted by the provinces then the same can be done on the lines as those of the Indian Medical Council Act. With a view to establish a uniform standard in the different branches of the engineering profession it would be advisable

to lay down the qualifications in consultation with the Local Centres and to start with we may have to be liberal to some extent while specifying the minimum qualifications which would enable engineers to be registered but we should at the same time see that the standard should be sufficiently high so as to ensure that necessary respect is commanded by a registered engineer in his dealings with the public. We trust that this measure may soon be enacted as one of the statutes.

In welcoming those who are elected as members of the Committee I take liberty to impress upon them the primary necessity and obligation to their regular attendance at the meetings of the Committee and of the General Body. We have before the Committee meetings several important questions bearing many a time on the well-being of the profession in general and the status of Engineers in particular, and mature consideration of such vital questions cannot be meted out unless there is full attendance of members. Let me impress on you once again that ours is the only Institution on the East of Suez which holds a Royal Charter and I fervently appeal to you, members of the Institution and more particularly to those in whom you have vested the reins of office for the ensuing year, to put forward an earnest and sincere effort to continue to prove ourselves worthy of that high honour, and I am confident that in exercising your right of voting you will give place to no consideration except merit and the compliance of our Bye-laws for the election of any individual to our corporate membership so that our selection may reflect credit on our choice.

I propose in my presidential address to-day to follow the same traditional course set up by the Presidents of this and other leading Institutions and to confine my remarks to works with which I have been associated. I intend, therefore, to deal with the problems of Municipal engineering.

Of all the amenities which the civilized communities enjoy, none is of such vital importance as the abundant supply of water which in its turn necessitates the installation of an efficient drainage system. It is equally important that the waste products receive final treatment and disposal so as to render them innocuous, hygienic and inoffensive. It is a matter

of gratification to know that this important service on which the health of the community so vitally depends can be carried out by incurring so trifling a liability to an average citizen.

Town sewering and house-draining are as ancient as civilization. Drain tubes of earthenware have been found under the mounds of the cities of Asia. The Romans sewered their cities and towns and drained their temples, baths and public buildings and the sewage polluted the adjoining rivers. Sanitary progress in Great Britain till 1875 was comparatively slow and the first rude sewers were more mischievous than beneficial. The earlier Norman castles were not sewered but were sinks of filth both within and without.

The composition of sewage, as you are aware, is not the same at any two places but even at the same place it varies from time to time and from season to season but the principal character of sewage remains more or less common to all of them. Generally speaking, it may be laid down that in a well-sewered town, the character of the sewage will vary in proportion to the time and hour of the day and to the habits of the population and it will be richest in the morning, at noon and in the evening. From a few hours after sunset to early hours of the morning—for 6 to 8 hours — the sewers will contain little more than subsoil water and waste from defective water supply fittings.

The treatment of sewage at any one town or district can only have a limited value, to a certain extent depending on the efficiency of the system and the accuracy of the testing. It may, however, be stated that any single example will not have much value outside the special conditions of the locality.

Turning to the question of maintenance of sewers and drains one cannot ignore the problem of keeping the sewers free from obstruction and which can only be attained by their periodical cleaning. The dangers likely to be manifested in sewers are of various kinds and the most important is the one from escape of sulphuretted hydrogen, carbonic anhydride and methane, leakages from the gas pipes overflowing of inflammable liquids with the production of volatile Hydro-carbons and combustibles. This gas is extremely toxic in its nature even more than oxide of carbon. Messrs. Audibert & Delmas

carried out a number of experiments and their observations based on a series of cases of accidents caused by suplhuretted hydrogen led them to identify two forms of intoxication by this gas, one of sub-acute nature which was characterised by irritation of mucous membrane and the other of acute and consisting of paralysis of nerve centres. In the case of sub-acute intoxication a period of several hours spent in an atmosphere containing from 5 to 20 one hundred thousandths of sulphuretted hydrogen or a period of 5 to 10 minutes in an atmosphere of 50 to 60 one hundred thousandths of sulphuretted hydrogen sets up a progressive irritation of the mucous membrane, first in the eyes, then in the throat and finally in the lungs. If the action of the gas continues, the resulting pulmonary oedema may finally cause death. As for acute intoxication, a stay in an atmosphere containing one thousandth part or more of sulphuretted hydrogen causes almost immediate unconsciousness and asphyxiation of the victim. The death often supervenes before measures for restoring consciousness can be adopted. To prevent such occurrence in the sewers and to safeguard the men working in them, preventive measures should invariably be taken and may be classified under the following main heads :—

1. Control of waste water in sewers.
2. Regulation of positions of gas main in public streets.
3. Maintenance of sewers.
4. Improvement of the material in the sewers.
5. Providing all possible ventilation in the sewerage system.

As would be seen from the above there are certain points on the sewerage system where accumulation of gas is likely to take place which may lead to explosion if it comes in contact with fire. To avoid any explosion taking place, upto very recently Davis Safety lamp was used, but even in case of the use of the Davis Safety lamp, explosions had occurred resulting unfortunately in a few cases where persons working in sewers particularly at night time were burnt to death. The Davis Safety lamp is now eliminated and instead, electric torches are

used to minimise the danger of explosion taking place in the sewers, and thus safeguarding the men working underneath. No doubt it might be argued that a provision of an efficient ventilation system should to a great extent do away with or at least minimise the danger of explosion occurring in the sewers, and this object may also be more so achieved by opening up a series of man-holes on either side of the man-hole in which the workmen are allowed to enter before the actual work is started, but it has to be observed that in actual practice it has sometimes taken several hours in this City to make the sewers safe for the workmen to enter into them and work therein without any danger to their lives. The problem of sewage gas or sewer air as it is frequently termed is one of a dangerous nature which requires careful handling. In the designing of any sewerage system particularly in tropical countries, where generation of gas due to a higher temperature is more likely to occur, devices of liberation of this gas at heights where it can cause no inconvenience or nuisance to the public in the neighbourhood should be provided on the sewerage system.

I shall now briefly deal with the problem of house drainage. I need hardly emphasise that it is impossible for a Municipal Engineer to prepare the drawings of every individual house in a big city like Bombay or afford to give the same supervision as he would think necessary for the works for which he is directly responsible. His duty consists only in the scrutiny of plans and to see whether the bye-laws are complied with or not, and it is not possible for him to deal with details of planning of house drainage, plumbing and sanitation of the various buildings in a big city. Plumbers may be competent in their own line of work and the building contractor is generally a man of great and wide experience and knowledge and left to themselves they would usually produce very good work of excellent design. But they have in many cases to work under a great handicap which at times is due to their being asked to carry out work in accordance with a faulty specification given to them. In some cases the sanitary work is attempted to be hurried through with a view to get the building occupied as early as possible. It is my unfortunate experience that many of the Architects who, I believe, should take a keener and greater interest in this direction, are themselves, I am afraid, ignorant of house-drainage. It is not a matter of uncommon knowledge that in many cases

the landlords do not grudge large outlay of capital on all other parts of construction of the building more particularly those parts which are visible but when the question of incurring expenditure on the underground works and sanitary fittings is to be tackled, the same is looked at from a different standpoint altogether. It is this stingy consideration of the execution of underground works which results in bad design, poor workmanship and the ultimate expenditure on such imperfect work is as a rule far heavier than those done under proper care and supervision of a competent Engineer. With the exception of Municipal Engineers, I think, there are a few persons in the profession who can speak with authority on the subject of house-drainage. I am particularly referring to this aspect of engineering as I think house-drainage is one of those principal matters for consideration in the construction of a structure which requires far greater attention in its design and execution than the share it has received so far. Defective house-drainage has given rise, to my knowledge, in many cases to the out-break of enteric cases and in one small group of buildings, 17 cases had occurred in a period of 6 months. The outbreak of further cases was arrested after the drainage fittings were looked into and the defects rectified. I, therefore, think that the local authorities might look into this question and if necessary, get the requisite powers from the legislature in cases where they have none, and it may be suggested that just as we have Water and Building Bye-laws of the Municipality of Bombay, the present drainage rules and regulations may be substituted by the drainage bye-laws of a more stringent nature.

The amendments of the various sections of the City of Bombay Municipal Act and the Building Bye-Laws framed thereunder have been suggested by the Municipal Executive and very exhaustive and comprehensive suggestions to give effect to those amendments have been put forward. The local centres of the Institution received a copy of those proposed amendments and the same have duly been considered by your Committee. Two general meetings of this centre for the discussion of these draft amendments were also held. In the year to come this question will surely engage the attention of the Engineers and Architects of this City as many of the suggested provisions will be vitally different from those that are in force to-day. It is undoubtedly agreed on all sides that the Building-Bye-Laws of the Municipality are antiquated and have not

kept pace with the fast changing conditions of the City and more particularly with the mode of construction. Even in the present draft amendments no mention has been made of R.C.C. work but the same is under consideration and further suggestions in that behalf will be put forth in due course. In this connection let us clearly understand that no legislation can be perfect or fool-proof from every point of view, but endeavours should be made to assist in the best direction in the amendment of our existing Bye-Laws with a view to bring them up to the modern standard and persevere in our efforts to remedy defects, if any, which are noticed in their working. Wider powers to some extent have been sought to be conferred on the executive and there should be on this score no ground for apprehension. If we reflect on the large amount of dealings the public have with the Municipality in the disposal of plans and their other proposals and to the general satisfaction and mutual co-operation which exist between them and which, we trust, should form the basis of working of any legislation which might control the building activities in the City, we should have no apprehension. Such mutual understanding and co-operation shall sink the apparent differences which might be existing and will form a basis of evolving ultimately still better bye-laws governing the disposal of building proposals.

Of the many questions which engage the attention of those concerned with the welfare of this City, the clearance of its slums is one of important magnitude. It is a matter of satisfaction that our Municipality have already set their hand seriously to this task and are endeavouring to solve this vexed and essential problem in the best possible manner, commensurate with the financial implications which are undoubtedly of a very heavy nature. The question of slums is to a great degree linked with that of housing and it is clear from the report of the Rent Enquiry Committee that the average population per inhabited building is 38·10. The Committee's finding on the pressure of persons upon room space is stated in the following terms:

"The total number of persons living in rooms each occupied by 6 to 9 persons, 10 to 19 persons and 20 persons and over, is 2,56,379; 80,133 and 15,490 respectively. Every third person in the City therefore lives in such frightfully overcrowded conditions."

A reference to the Census figures of tenements by rooms and population reveals the same lamentable plight. "There are in the City 2,44,121 occupied tenements. Of these, 1,97,516 consist of one room only. One room tenements form 81 per-cent of the total tenements in the City and they are occupied by 7,91,762 persons or 74 per cent of the population of the City. The average number of persons per room in this class of tenement is 4·01. The facts then are, briefly, that three out of every four persons in Bombay live in single rooms and that in these rooms, with each of them, there are at least three other persons. It is perfectly impossible to view a situation like this with complacency."

The present Building Bye-Laws lay down the minimum area of a living room to be 100 sq. ft. but the Municipality in its recent construction of housing accommodation have provided the minimum area as 180 sq. ft. Since the publication of the Census report some 8 years back, the population of this City has increased by two lacs and the net increase in housing accommodation consisted of 19,018 one room tenements, 9,936 two room tenements and 8,394 larger tenements leaving nearly 50,000 people still unprovided for, on the assumption that the average persons per room remained the same as it was in 1931, when the last census was taken. The sad effect of overcrowding has its repercussion in the high incidence of infant mortality. This is borne out by the fact that in 1936, 71·6 per cent of the children were born of parents living in one room tenements while the percentage of deaths in that class of infants was 78·3.

During the last 3 or 4 years the Bombay Municipality have materially improved the standard of housing and have constructed about a couple of thousand single room tenements in ground floor structures with adequate open spaces. The open spaces are partly paved and partly kept as recreation grounds for children to play thereat. The space of the room area and the open spaces per tenement on the present day computation works out to be from 60 to 70 sq. yds. Every room is provided with a nahani, shelves, and pegs. All modern sanitary conveniences are provided and the open spaces are adequately lighted. The net return on this outlay to the Municipality is of course not sufficient to cover the interest and sinking fund charges, but we afford better housing facilities which must improve the health condition of those who reside

thereat. It will thus be seen that every effort has been made by our civic body to provide housing of a better standard and a great many amenities are provided and we are moving with the time.

Housing is one of the essentials of life which, it is regretted, has not so far been tackled very seriously in this City, but no Municipality however great its resources will be able effectively to solve it because the bigger the City the greater will be its needs. It must, however, be mentioned to the credit of some of the large employers in the City that they have provided housing accommodation for their labourers. This problem—a problem which concerns particularly so vitally the life of the poorer classes—can be expeditiously solved by the joint efforts of the Government, Municipality, Port Trust and all important owners of Mills and Factories.

A quicker way to improve the housing condition in the City would be to subsidise housing and in this connection one has only to refer to the beneficial effects which such legislation as Addision Act of 1919, Chamberlain Act of 1923, Wheatly Act of 1924, Greenwood Act of 1930, Housing Acts of 1933 & 1935 produced in Great Britain. Briefly speaking the housing problem may be described under the three main heads—

1. The need of demolition or thoroughly re-conditioning of insanitary buildings.
2. The abatement of overcrowding.
3. The provision of additional housing accommodation to cover the influx of and natural increase in population and to replace the dwellings which are required to be pulled down due to their being past the state of repairs.

In respect of Road construction, the City of Bombay has made considerable progress during the past decade or two. Since 1921 the Corporation have adopted the policy of building modern surfaces suitable for withstanding motor traffic. Although such surfaces have been found to last long and to require a nominal maintenance their initial cost is comparatively high. To meet this cost the Corporation decided to raise loans, and roads so built are known as 'Capital Roads'. Experience

of the last eighteen years has fully justified the loan policy of the Coporation and the annual savings in maintenance on Capital Roads has been found to be about 30 per cent of the former cost of maintaining them by the old practice of water-binding. Apart from this saving the roads are now cleaner, do not cause delays to traffic, lead to better acceleration and save considerable sums to owners of vehicles thus popularising motor travel and cheapening goods transport. The improvement in the road surfaces coupled with that in drainage and water supply has also resulted in a betterment of the health of the population.

The methods of road construction adopted are as follows :—

Sheet Asphalt.

Asphaltic Concrete.

Premixed Asphalt Macadam.

Penetration Asphalt Macadam.

Surface-dressing with Asphalt.

Stone-sett Pavement.

Cement Concrete.

Stone-sett pavement has been used principally on roads near Docks carrying heavy goods traffic. In general they have given good service but now after about 17 years' use the pavement has been uneven and noisy. It has also become insanitary on account of road dust getting lodged in it.

It has been found advisable to resort to cement concrete construction on narrow zigzag residential lanes, where other methods of construction are not feasible on account of the difficulty of rolling. In these lanes concrete has given good service. Outside these lanes we have concrete on other roads, some carrying heavy traffic.

The bulk of our road work has been with Asphalt. The earliest Capital Roads laid with Asphalt are now eighteen years old and have given very good service to date.

All Capital Roads have been built with a heavy foundation made up of cement concrete generally laid 6″ thick. Revenue Roads are all on old foundations built either with rubble or a thick layer of metal.

In a City like Bombay foot-paths are essential. Whilst many of our newly built roads have been provided with them, the bulk of old roads are without good foot-paths. Their construction has not been very satisfactory. With an increase in the number of motor vehicles the provision of pucca foot-paths has become an absolute necessity and the Corporation now have on hand a scheme for improving a large number of foot-paths. The programme is for about 12 years.

We are all concerned, one way or another, with the traffic problems which face public authorities of to-day. The density of traffic on roads is not only steadily increasing but is increasing during dark hours. Heavy goods traffic once taken by rail is being carried to an even greater extent on roadways at night and this, together with the enormous development of omnibus services has caused the value of modern street lighting to be recognised to a greater extent than ever before.

It is true to say that road accidents bear some relation not only to density of traffic but also to the visibility afforded to all road users, pedestrians and drivers.

An efficient public lighting scheme is one that makes readily visible to any observer, whether moving or stationary objects in the field of vision. This represents the advance which has been made in the practice of street lighting in the past ten years or so; the days when lamps were placed at street corners and judged by the amount of light which they emitted are gone. A specification for the illumination of our thoroughfares now-a-days indicate the amount of illumination required to be placed on the carriageway, in other words, the visibility provided. We now speak of the Foot-Candle illumination of a road, the foot-candle is the illumination produced on the surface of a sphere having a radius of 1 foot by a uniform source of one candle situated at its centre. Uniform road brightness, or the avoidance of "Pools" of light under the lamps and of dark areas between them is now the principal consideration when designing a scheme and the lamp Manufacturers, both Gas and Electric, now produce lamps which are not only 25 per cent more efficient than a decade ago, but are so designed and fitted with Directional Reflectors and/or Refractors that the whole of the light output is utilised on the road and evenly distributed.

The road surface which has been designed by the Road Engineer from considerations of wear and non-skid properties, is the background which the Lighting Engineer has to illuminate. It frequently happens that the more non-skid the surfaces are, the greater the difficulty to illuminate the surface uniformly. I may quote a good example of this fact which most of you remember. I refer to the result of rendering the surface of the Marine Drive non-skid just before the monsoon of 1938. The designs of corners and cross roads together with their backgrounds, the correct positioning of the units and their mounting heights, the reflective properties of buildings flanking the streets and the design of the lanterns and lamps are points in this complex problem with which Municipal Engineers are fully acquainted, but, as Street lighting is a public service, the greatest efficiency must be provided at the smallest expense and the question of finance is perhaps the Engineers' biggest problem. I feel certain that when the general public understand what good lighting of roads and streets really means to them they will not only sanction more expenditure but will demand it.

Almost two years back the Municipality undertook the widening and reconstruction of Love Grove Bridge. It is 132 feet in total length and made up of 3 numbers 38′ clear spans supported on 6 feet wide piers and abutments of varying width. The construction is made on the side of the existing bridge which formed one of the two notorious bottlenecks of Bombay. The eastern half is founded on the existing piers and abutments with necessary modifications while the western portion of the bridge is erected on entirely new foundation piers and abutments with the exception that the northern abutment is raised over the existing structure and extended towards the west for the widening of the bridge. The piers and abutments are taken down to hard murum and the foundations have been laid in 1:3:6 mass concrete up to channel bed from where upto the beam seats the piers have been constructed in 1:2:4 concrete and the abutments in 1:3:5 or 1:3:6 concrete as circumstances warranted. The beam seats have been strengthened with mat reinforcement and the western halves of the piers and abutments have been stepped out at their eastern ends for making solid junctions with the

existing piers in the eastern half of the bridge which were were similarly stepped out for the construction joints. Sufficient number of iron rails have been laid in the construction joints to transfer the bridge load evenly on the foundations. The deck slab of the bridge is carried on 14 numbers R.C.C. girders placed 7′-2′ centre to centre with a centre overhang of 1′-1½″ in each half which is separated by a longitudinal ¼″ expansion joint. The slab of R.C. construction is constructed in two sections, 10″ thickness for the vehicular traffic and 9″ thickness for the foot-paths which are 15′ in width out of the total width of the bridge of 90 feet between the parapet girders. The design is worked out on the ministry of transport loading with 40 per cent impact. Before the girder reinforcement was laid in position, the beam seats were smoothened with carborandum stone so as to minimise temperature and shrinkage thrusts on the piers. ¼″ expansion joints between the longitudinal beams and slab in each section have been constructed of premoulded bituminous filler which was tacked on to the finished surface of the concrete before the concreting of the adjacent span. The central longitudinal joint which divides the bridges into two halves was also similarly treated. Concreting of the deck slab and the supporting girders was done in six stages. Each stage represented 41 brass of concrete and it was finished in 5½ to 6 hours with 4 concrete mixers. This is the only work in Bombay that dispensed with deposition of concrete by head loads and employed light steel hand carts of about 3 cft. capacity to carry the concrete to the required place. Only two men were required for individual trucks and considerable saving in laying cost resulted. The trucks were rolled on to the specially prepared platforms with great speed and were instrumental in keeping the concrete in a fresh condition. The screening on the deck slab was carried out by means of wooden templates running on $1\frac{1}{8} \times 1\frac{1}{8} \times \frac{1}{8}$ angle irons fixed on timber pieces of 10″ height. The latter were made conical in shape to facilitate easy extraction after the concrete was dry. The deck slab is covered over the expansion joints with ⅛″ steel plates 8″ wide fixed on one end with bolts and the other free to permit the slab expansion and construction. The plates resist the running down of the asphaltic matrix into the joint and consequent disintegration of the road surface. The deck slab was finished with asphalt Macadam 1¾″ and a seal coat of 1¼″ thickness

laid hot and finished true to camber with steam rollers. Before the road was opened to traffic, the seal coat was sprayed with $\frac{3}{8}''$ grit and rolled to prevent skidding.

The old bridge had six gate openings for stopping the incoming tides into the City. These had to be removed as the openings had been enlarged to 38′ for further requirements of the waterway. But before this could be done, the Municipality had to extend the existing sea wall across the channel and provide the automatic tidal flap gates within the wall so as to block the tides. The existing wall is constructed out of precast concrete (1:3:6) blocks each weighing about 5 tons. It is about 15′-6″ wide at the base and upto 16′ feet height, it is of the same thickness, but the last 4 feet is tapered by 1 ft. both on the sea and the channel sides. The extension was constructed in the same profile with precast stones of identical weight. During the period that the wall was being completed a cofferdam was constructed to enable breach being made in the central portion of the wall for building in the flap gates. The cofferdam was made with murum filling between timber walls 6 ft. apart which were taken down to rock level in the bed of the channel. It proved fairly water-tight and gave little trouble during the concreting of the flap gates and laying foundations for the bridge. What trouble we found was on account of the sea which sent down waves over the cofferdam and inundated the whole site. Pumps had therefore to be made on the western face of the sea wall 4 ft. lower than the sill level of the flap gates and continuous pumping night and day had to be done to get rid of water accumulating twice during the high tides. After completion of the cofferdam the existing sea wall was blasted out with dynamite and gun powder as circumstances warranted use of each.

It will thus be evident that there is a wide and varied range of subjects in which a Municipal Engineer can interest himself and it will be easily realised how much the welfare and happiness of citizens depend on the work of a Municipal Engineer.

Before I resume my seat let us hope that we may have many important discussions on various engineering subjects so that this Centre may serve as a medium of diffusing knowledge and transmit experience gained on the practical side of our profession.

Address delivered by Rao Bahadur C. V. Krishnaswami Chetty, M.B.E., B.A., B.Sc. Tech., A.M.I E.E., M.I.E., (Ind.) at the Annual General Meeting of the South India Centre on the 2nd December, 1939.

Gentlemen,

I cannot adequately express how grateful I feel to you, for the honour you have done me in electing me once again as your Chairman. This honour carries with it the great responsibility of properly conducting the affairs and guarding the interests of the South India Centre, entrusted to my care. Having been a member of this Institution since 21st June, 1921, Secretary of the local Centre in the years 1923-24, 1924-25 and 1925-26, Chairman in the year 1933-34 and also from April this year to the present day, I do not feel diffident to assume responsibility for a year more. But to make it a successful year of office, the hearty co-operation of all the members of the local Centre is very essential, and I sincerely hope that this co-operation will be forthcoming in abundance. I should however be failing in my duty if I do not explain what exactly I mean by co-operation and what exactly I expect of you during the coming year. First and foremost, regular attendance at all our meetings, is very essential, if our Centre is to give a good account of itself at the end of the year. Contributing papers, taking part in discussions at the meetings and joining in excursions and visits are not by any means less important. Above all, I should like to impress on the minds of our members the necessity for good comradeship. The senior members must make the junior members feel quite at home in the Institution. There should be something like a masonic fraternity among our members and every one should work disinterestedly for the Institution.

QUALITY SHOULD NOT BE SACRIFICED FOR QUANTITY

In its desire to swell the number of members South India Centre should see that quality is not sacrificed for quantity. The more strict we are in admissions, the greater is the desire to gain admission into the Institution. Our aim must be to raise this Institution to the level of the older engineering

institutions of the west, by raising the standards wherever necessary. The granting of a Charter to this Institution by His Majesty is a distinct landmark in its progress.

ENGINEERING ACTIVITIES IN SOUTH INDIA

The engineering activities in South India are not in any way behind those of other provinces. The hydro-electric projects at Pykara and Mettur, with their long transmission lines feeding innumerable sub-stations scattered all over the southern peninsula, the thermal stations at Bezwada, Cocanada and Vizagapatam with their respective transmission lines and sub-stations and the eventual Electric Grid linking up the thermal station in Madras with the hydro-electric stations at Pykara and Mettur, all these and many more future extensions and projects will absorb for many years to come young men passing out of our engineering colleges. The use of electric pumps in agriculture is becoming increasingly popular, owing to the availability of cheap electric power. This together with the increasing use of electricity for various other purposes affords employment to men skilled in various branches of engineering science. The South Indian Railway which has already electrified the line from Madras to Thambaram, a distance of eighteen miles, has given a distinct lead in South India in the matter of railway electrification. The advantages derived by the public are so great that the wish of the people of South India is for the extension of electric train service in various parts of the province. Sooner or later these things must necessarily come to pass. All the above projects absorb into service not only Electrical Engineers but also Civil and Mechanical Engineers. In the field of Communication Engineering, the rapid extension of Government telephone lines and the use of Carrier System have made the people telephone-minded. Business people especially, use it so much that their business would be paralyzed if the telephone services are stopped even foı a few hours. South India is forging ahead even in the matter of Broadcasting. There are already three stations working, two at Madras and one at Trichinopoly. In due course there will be one in Andhra Desa. Some of the South Indian States are already arranging to have their own broadcasting stations. Like the gramaphones, radio receivers are being looked upon as indispensable things in each household.

What an army of men skilled in Communication Engineering is necessary for the maintenance of all the above telephone and radio services !

While the activities in the various branches of engineering mentioned above are greatly manifest in South India, the progress made so far in the matter of constructing good modern roads, especially trunk roads, is not by any means satisfactory, despite the fact that big buses and heavy lorries are plying in ever increasing numbers between various towns in South India. The people are just beginning to realize the advantages of having real good roads made according to modern technique, and it wont be long before the demand for such roads manifests itself all over the province. The use of reinforced concrete for buildings is still at its infancy in this province. Sanitary Engineering projects also have not made appreciable progress. The harvest truly is great but the labourers are few.

PROJECTS GET A SET BACK ON ACCOUNT OF THE WAR

Many of the projects have received a set back as a result of the war in Europe and presumably some of the men may be temporarily thrown out of work. Every cloud has its silver lining. The war has brought home to the people of India their utter dependence on other countries for most of their daily wants. It has opened the eyes of the people to the urgent necessity for starting various industries and especially key-industries. If the impetus now given to industrialization is not taken advantage of, I am afraid, India will ever be dependent on other countries for most of her wants expect food. The use of modern machines and implements for agricultural purposes has not made much headway. In this as well as in the industrialization of the country, the engineer must of necessity play a very important part. Just imagine, gentlemen, what great scope there is for an engineer with energy and resource. You need not go abroad for work. There is plenty at your very door.

AN ERA OF INDUSTRIALIZATION

We are just entering into an era of industrialization. But without proper planning and co-ordination at this juncture, one must admit, the results cannot be satisfactory. The

National Planning Committee organized last year with the financial support of the Congress Governments of Provinces and some of the Indian States is working in the right direction, but unless the financial support is kept up, it cannot be expected to do much useful work. Our Institution must place at the disposal of the National Planning Committee all the techincal assistance it can give. Our Institution must play an important part in the industrialization of the country. It cannot be denied that this is the psychological moment for doing so.

ENGINEERS SHOULD FVINCE GREATER INTEREST IN THE POLITICAL LIFE OF THE COUNTRY

Gentlemen, great constitutional changes are expected to take place in the near future in the Central Government. Are the engineers going to play their part in shaping it or sit quiet with folded hands, leaving the whole work to lawyers and others ? Time has come for the engineers to evince greater interest and take part in the political life of the country. They must discard their inferiority complex and show that being practical men, they can acquit themselves creditably in practical politics. Learned professions are no longer only three in number. Who will now deny the engineering profession its place of honour? Therefore, you gentlemen of the engineering profession, please take time by the forelock and contribute your mite in shaping the destiny of India.

A USEFUL INDEX

There are quite a large number of engineers representing various branches of engineering in the area covered by the South India Centre, who have not become members of our Institution in spite of their being eligible for admission. The wider is the circle of membership, the greater is the scope of usefulness of the Institution. It would be well if the South India Centre prepares statistics in this repect and arrives at a factor showing the proportion of members to the total number of engineers (members as well as eligible non-members) in the area covered by the South India Centre. This will be a useful index in various ways for purposes of comparison from year to year. The aim of this centre should be to raise this factor to unity in due course.

COMRADESHIP AND FELLOW-FEELING

Gentlemen, in the early part of my speech, I exhorted you to attend our meetings regularly. You may ask how far is this practicable. South India is such a vast place and the engineers are scattered all over the province. It is alright for those in and around Madras to go to the premises of the South India Centre, and it is equally convenient for those who are in the service of the Government or Railways to attend the meetings, for they can arrange their tour of inspections in such a way as to be present at the meetings conveniently. But what about those who cannot do so? Even they, I am sure, come to the capital city occasionally and when they do come here, they must make it a point of visiting the premises of the South India Centre. If resident members would only make it a point of spending as many of their evenings as possible at the Institution premises, the mofussil members will find there somebody to talk to. The members can exchange their ideas, mould their schemes in consultation with others and foster comradeship. The sooner the premises is used as a club, the better. I visualize a day when the Institution will have a premises of its own in Madras, with a number of lecture halls, a big library, a spacious reading room, a restaurant, residential quarters for mofussil members, huge halls buzzing with people at all times of the day and extensive sports ground etc., etc. We may have all these and many more, but what is the use if comradeship and fellow-feeling are absent. I exhort you, gentlemen, to see that these qualities do not desert you, so as to ensure smooth and harmonious working of the South India Centre.

Gentlemen, I thank you once again for the honour you have done me by appointing me as the Chairman of the South India Centre for the ensuing year.

Address by Rai Bahadur B.P. Varma, M.I.E. (Ind). at the Thirteenth Annual General Meeting of the North-West India Centre on the 10th February 1940.

Gentlemen,

I must first of all thank you most cordially for having elected me a second time the Chairman of the North-West India Centre of the Institution of Engineers (India) for the

year 1940. This is the second occasion when this honour has been conferred upon me by the members of this Centre, but Gentlemen, excuse me for saying that I am feeling like that schoolboy who is given a double task because he had failed to learn his class lessons properly. Unlike the schoolboy whose punishment was short and swift and ended that very day, mine has followed after seven years and due to failing health, who knows, I may not succeed in doing my task satisfactorily this time again. However, I propose to do my task and hope all of you will kindly lend me your unstinted support towards the common cause of the profession and the good name of the Institution to which we all belong.

As Luck would have it our profession (Engineering) easily stands out as the best and the foremost of all others professing to render service for the good of the country and its people. Every Engineer should therefore be proud of the power, to do good to others, vested in him by a kind and thoughtful Providence. This would show that "Service" should be the watchword of every Engineer who professes to be true to himself. Our Institution, having taken upon itself to bring together in fraternal bonds the Engineers of this vast country, has opened out a new vista for rendering service, to all its members. All Engineers should welcome this opportunity and take advantage of it not only by becoming members of the Institution, but by providing as far as possible, all necessary materials to enhance the reputation of the Institution and to build up suitable traditions for which posterity would remember us thankfully.

In my Address as Chairman of the Institution in 1935, I had expressed certain views. Some of these wishes and important ones at that, are near about fulfillment and I am therefore sure that you will excuse me if I quote below *in extenso* the objects I then had in my mind.

"I also think, and it will be readily admitted, that unlike other countries, the conditions under which engineering works are undertaken, designed or built change from province to province in this country, and require particular treatment and handling; and for this reason also the collection of a variety of experience has become a necessity for the profession.

For all these reasons I wish and would recommend that a bureau be formed and administered by this Institution, dealing separately with all its branches. It may not be possible to make a start on a comprehensive scale dealing with all the branches, but we may begin with as many as can be tackled at present, adding on others and sub-dividing all or any of them as necessity arises or experience demands. I would suggest the names of the following branches of engineering with a central office at Calcutta and branches at suitable local centres for a beginning :—

1. Civil Engineering.
2. Electrical Engineering.
3. Structural and Architectural Engineering.
4. Sanitary Engineering.
5. Mechanical Engineering.
6. Metallurgical Engineering.
7. Industrial including Technological and Chemical Engineering.

Engineers, as a rule, are generous in imparting their own experience and knowledge to others, and I therefore feel quite confident that our own members, and other eminent engineers not as yet within our fold, would help our Institution in this undertaking.

It is one of the primary duties of the Institution to see that young engineers receive a sound theoretical and practical training and that a high standard of education is maintained by engineering schools and colleges in India. There are a number of these institutions, some old and others comparatively new, imparting education in certain branches of engineering. In the last century when the profession of engineering was not much in favour with Indians and the number of colleges was also small, Government Services used to absorb nearly the whole of their output and any surplus, if left, used to find employment in industries and trades. In the present century, engineering schools and colleges have increased—in fact, each Province can

claim at least one to itself, if not more—and consequently the number of engineering students and graduates has been increasing from year to year, so much so that it has become impossible to find employment for them in the services under the Government of the country. Undoubtedly trades and industries have also been developing side by side and ought to have absorbed a large number of young engineers for work and training, but unfortunately, on account of financial stringency and trade depression, this has not been possible. The engineering schools and colleges of India should therefore try to keep abreast of the present-day requirements of the trades and industries of the country. Their technical courses should be moulded as far as possible in accordance with those requirements and their practical training should also follow suit. More importance should be attached to specialisation, because without that it would be difficult for students to find employment in trade or industry. In short, the students should be prepared as much for employment in trades and industries as under Government, and the training imparted should be of a nature to befit them practically for some special class of work."

The Institution has already appointed a strong Education Sub-Committee, which is about to start work. It has also agreed to form an Information Bureau at the Headquarters though the details have not actually been chalked out. The Sub-Committee appointed for the purpose will have to do real hard work in settling the details. Some one might perhaps say that all this would be a gigantic task and so it no doubt would be, but nobody would deny that the expansion was much needed and in the right direction. The Institution at their last Annual General Meeting fully realised their position in this respect and have agreed to appoint a Technical Secretary to take charge of this and other similar work. I hope that this step would prove effective towards organising the work of the Institution. Gentlemen, you will thus see that we are expanding in right earnest and increasing our usefulness towards the members of the profession in general.

The situation in Europe and the world conditions due to War have considerably changed our outlook even though India has not yet been directly affected. Those branches of Engineering that loomed large in importance before the War, such as

Nos. 1 to 5 in para 3 supra, have now assumed a secondary role of importance and quite rightly too. Metallurgical, industrial and chemical branches of Engineering have come to the fore according to the industrial and agricultural needs of the various provinces of this country. With your permission I will again quote from my address of 1935 to show how necessary it is for us to develop suitably in all branches of the profession in order to keep pace with our professional brethren in other countries.

"For this class of development work engineers with imagination, self-confidence and character will be required, but they alone will not suffice, and nothing will be done till they join hands with a body of industrialists well qualified and trained in their own lines. This combination of capital, intelligence and labour should result in an addition to the productive capacity of the country and its output of manufactured articles, and thus inaugurate an era of economic prosperity. This plan has been tried and has proved successful in other countries with much limited resources as compared to our own, and I do not see why similar results should not follow our efforts in this country."

Gentlemen, now I will request you to kindly pardon me for not being present at the meeting to-day. I had already anticipated such a contingency and in order to avoid it had asked for a date towards the end of February 1940 for our meeting. This, however, could not be arranged as the old proverb hath it "Man proposes but God disposes". Thanking you all again and with regrets for my unavoidable absence, I still hope that with your sympathy, co-operation and loyal support, all will be well with the work of this Centre in this year 1940.

Address delivered by Mr. B. R. Garudachar, B.E., M.I.E. (Ind.) at the Fifth Annual General Meeting of the Mysore Centre.

Gentlemen,

It is a matter for great pride and pleasure to us that our Dewan has, amidst his multifarious duties and engagements, been able to graciously accept our invitation to open this joint Session and his presence here to-day is a source of great encouragement to us. I beg to convey our thanks to him for the

great interest he took in the formation of this local centre of the Institution of Engineers and for his kindness in acceding to our request to be present here to-day.

My thanks are also due to the members for having elected me the Chairman for the ensuing year. Though I accept the same with some amount of diffidence, I hope with the co-operation of the members of the Committee, I shall be able to shoulder the responsibility of the place and further the interests and activities of the Association.

Before proceeding further, I wish to thank on behalf of the local Centre the retiring Chairman, Mr. N. Sarabhoja, who as you all know has done good work in the last year.

It is not my intention to weary you with a long address but still I wish to speak a few words on the important topics in which we are directly interested.

The Science of Engineering is advancing rapidly and if an Engineer wants to be really successful in life, he has to keep himself in touch with new developments.

I am glad to point out that the progressive and enlightened policy of His Highness' Government afford Engineers ample scope for the display of their professional abilities which comprise within its range important schemes of development.

The population of Mysore is growing by leaps and bounds. It is doubtful whether they will be able to earn a living out of the land. Industrialisation has been suggested as one of the methods of providing employment to the increasing population. With the starting of various industries in the State, there will be appreciable diminution of unemployment in the Engineering profession.

Some Engineering graduates who have taken up contract works have been getting on well. I will however advise them to go out and see how big works are carried out in other parts of India. This will give them additional and valuable knowledge.

Turning to roads, the problem of road maintenance has become very acute owing to the ever increasing traffic and to advent of motor transport even in the most interior parts of the State. The inefficiency and high ultimate cost of water bound macadam in many places has become apparent.

Various experiments have proved clearly that a combination of rubber and iron tyred traffic is together far more damaging than would be the sum of the two taken separately. The problem in India has thus for some years been to provide a dual purpose road. Some roads have no doubt been constructed in some parts of India with alternate strips of concrete and asphalt with the object of automatically segregating traffic. Bullocks are attracted by concrete surface owing to the lower tractive effort required but for fast moving traffic asphalt surface has been found quite advantageous. Cement concrete roads have been of late receiving greater attention. They have been preferred in places where the traffic is of heavy bullock carts with iron tyred wheels.

As regards earth roads they form the links between villages and the main roads and carry the whole of the traffic from the fields before they reach the metalled road. They are, therefore, of vital importance in the economic development of the country and their improvement plays a very important part in rural development. It has to be admitted however that the problem is a very difficult one and greater attention has to be paid for its solution than what has been done in the past.

Recent experiments have gone to show that this problem is mainly one of soil and the behaviour of soils under various climatic and traffic conditions has to be investigated before suggestion for improvemnet of such roads can advantageously be made.

The capillary pull of soils and sand with special reference to earth road research is one of the subjects for investigation. This will be useful to determine the effect of a layer of sand to prevent rise of salt in the case of these roads.

Next turning to Irrigation, Mysore, like the rest of India, is predominantly an agricultural country and agriculture, her chief industry, is dependent to an essential degree on irrigation. Mysore possesses a very good irrigation system and a very great sum has been spent on it.

According to latest available figures 10,88,985 acres of wet land are irrigated by tanks, wells and canals. The facilities given by Government in the shape of a net work of irrigation

canals and the restoration of Major and Minor tanks and pumping facilities by supply of cheap electric power, all these have helped to improve the economic condition of the agriculturists.

That our Government recognise the economic importance of irrigation is clear from the number of new projects under construction or under consideration.

One of the most important things in connection with irrigation is the question of sub-soil water survey in irrigated areas. This is a matter of great importance from the point of view of preventing water logging and consequent malaria and deterioration of the soil by the accumulation of salts.

Another subject equally important is the effect of deforestation on irrigation projects. Deforestation and soil erosion not only intensify flood and aid in the silting of our tanks but also they threaten our Sub-soil water supply and impoverish the soil. So a successful defence is of very vital interest.

Mr. Sarabhoja in his Presidential Address last year has referred to the necessity of starting a Research Station for irrigation in Mysore. I reiterate it on account of its importance. The establishment of such a station is essential as it will make a material contribution towards the solution of a set of problems peculiar to these areas.

Gentlemen, I thank you once more for the honour you have done in electing me Chairman.

I now request you, Sir, to kindly open this joint Session of the Mysore Centre of the Institution of Engineers and the Mysore Engineer's Association.

Address delivered by Mr. Hasan C.A. Latif, C.E., M.I.E. (Ind.) at the Second Annual General Meeting of the Hyderabad (Deccan) Centre on 16th November, 1939.

Gentlemen,

I can hardly tell you how highly I appreciate the great honour you have given me by electing me once again as the Chairman of the Hyderabad Centre of the Institution of Engineers (India). Among the greatest of distinctions that can fall

to any man is that of being placed in a position where he represents those whose life work has been the same as his own. Considering that for a second year in succession you have honoured me by electing me to the Chair of this Centre I feel an added responsibility on my shoulders. I thank you very much for thus giving me a further chance of serving you, and I can assure you that I shall endeavour with the best that is in me to advance the interest of our Centre of the Institution.

We started this Centre with 65 original members, and in the course of the year have been fortunate in receiving several applications for membership. Many of our Engineers who have applied for membership will no doubt be enrolled in due course of time. We may regard this as satisfactory progress, but considering the many and extensive engineering activities of the State there is still much scope for increasing our Membership. It is indeed a disappointing fact that some of the Engineers from the allied Engineering departments have not thought it fit to join the Institution. There could perhaps be only one reason for this, namely that they do not seem to have felt themselves sufficiently interested in the engineering problems of the country. It is hardly necessary to point out that this Institution is an All-India Corporation of Engineers, interested in promoting the progress of *all* branches of engineering in our land. I believe that some engineers are inclined to think that because they are members of a similar English Institution it is not necessary to join the Indian Institution also. I would however tell these gentlemen that beyond the accepted theories, the actual practice in this country has to be widely different because of the totally different conditions, and unless our experiences are pooled together it would not be possible to make any scientific advance with regard to Engineering problems that arise in this country. The Engineer by virtue of his training is the exponent of action. It is therefore all the more necessary that by the co-ordination of experience we should be able to evolve methods involving the least waste of time and labour, which are otherwise likely to result from the overlapping of individual efforts, each trying to plough his own solitary furrow.

Our Local Centre held 8 meetings in the course of the year. These were on the whole fairly well-attended, although I think the attendance was not as satisfactory as it should have been. I would like to assure those who did not attend, that the

discussions on the various papers that were read were all of very considerable interest, and of helpful value in the day to day work of all engineers. It should not be imagined that if a paper is to be discussed which does not directly concern the engineers in their vocation, it will not interest them. The first principles of all Engineering are the same, but it would be found that a paper on a subject definitely unconnected with one's own line would yet have many points of interest in the conception of larger Engineering problems. Much useful information is revealed in discussions from the experience of others which every one has not the opportunity to acquire individually.

At our ordinary general meetings we are pleased to have engineers, who may not be members, as visitors. We appreciate their interest and enthusiasm. I hope more engineers will take advantage of this open invitation which would give them an opportunity of judging the value of the information that can be gained from discussions and which will induce them to become members of the Institution.

It is one of the primary duties of such Institutions as, ours, that young Engineers are given a sound theoretical and practical guidance, and that above all a high sense of discipline is inculcated in them. It is true of all professions and particularly true of Engineers, that their training must go on as long as they continue to be actively useful, for, the Engineer, who ceases to learn, stands to lose in utility value. The training is to be scientific as well as mental. The development of character is very necessary for the Engineer, as he, more than anyone else, is called upon to serve the public and is the custodian, nay, the accredited agent for expending public money. In his duties the Engineer has to rally to his side forces of self-reliance, self-knowledge and self-control.

This brings me to a subject which has remained nearest to my heart, and my experience of 33 years of public work has convinced me beyond doubt, that the essential need of our profession, and in fact every occupation of life, is a strict sense of discipline. Modern life has expanded beyond the limits of the individual and the family, and all efforts have to be governed by natural, social and scientific laws. Old occupations of agriculture and small cottage industries have not trained us for corporate effort. The efforts of the individual or the family,

have proved successful, because of the incentive of direct personal interest in the business. Corporate effort on the other hand needs the combined efforts of the members constituting the business organization without any special incentive except their wage. Hence the importance of every link in the chain of efforts being made to act in unision. Here each individual, to achieve the desired end, must do his allotted bit in the corporate effort. There is no room for personal considerations which degenerate at times into nepotism and indulgence.

The expansion of the means of locomotion has brought our country into competition with the outside World. Europe and America have been industrial countries for decades, and this has made their people mechanically minded, which in turn has led to the evolution of a highly organised system of big business. If therefore we desire that our country should develop on more or less the same lines of advance as the Western Countries, and to succeed in competition with others our Engineers and Captains of industry should develop in themselves the same methods of mechanical conception. By mechanical mindedness I mean that one should be able to apply, as a matter of course, to the daily business of one's life that sense of regularity and discipline which is represented by the working of an efficient machine. In other words each part should act in its allotted place with precision and regularity, regardless of any extraneous influence. It is an oft repeated truism that the strength of a link is the strength of the chain. If therefore one part of our organisation, be it service or business, fails, the result has a far reaching effect in clogging, if not throwing the entire machinery eventually out of gear. To illustrate my point I may tell you that I have seen a length of road which had cost about 6½ lacs of rupees to construct, but was found to have deteriorated in the course of a few months principally due to the neglect of a subordinate—quite an unimportant unit in the administrative chain so far as status and emoluments were concerned—and had to be resurfaced at a considerable cost out of all proportion to the value of the link to bring it back to its normal condition. Had this small pinion of the administrative machinery moved in its defined orbit, or had the other cogwheels worked in unision, this kind of public waste would have been prevented. In a machine such a link if it failed to respond to adjustment would break.

Our old philosophy of forgiveness and charity tends to overcloud the realization of the natural facts and is often misapplied. It must nevertheless be remembered that what our philosophy teaches us is to forgive sins against ourselves but not against those whose responsibility or confidence have been entrusted to our charge.

To you young men I will say that punctuality in your duties, timely attendance to your work and an ever-absorbing consideration to make your designs as economical as possible, should be the guiding factors of your work. It is only then that you would be able to prove your merit and make yourself really useful.

A wave of reconstruction is sweeping over this country. As you are no doubt aware, the National Planning Committee has initiated enquiry into the different problems of National life. There are many problems of great importance such as reduction in unemployment, evolution of industries, development of cheap electric power, saving in the maintenance costs, expansion of communications and transport development, housing, flood control and several others which await solution. In all these branches the Engineer is destined to play an increasingly important part.

The Great War which was followed by an economic war, had thrown the life of the entire world out of balance. It had brought the nations to the verge of bankruptcy. The World had hardly begun to recover, when, unfortunately, another crisis has been precipitated, and which we are passing through. When this is over, and let us hope and pray that it may be soon, there is bound to be an economic break-down in the absence of any plan of adjustment. To a poor country like India the problem of adjustment is bound to present incalculable difficulties which could alone be overcome by a common consideration and common action. If on the one hand it would demand the efforts of Statesmen, it would on the other undoubtedly need the energies of industrialists and Engineers. The Engineering problems that arise from day to day are, in the main, the creation of the present day environments, and their solution, which involves costly undertakings, requires Engineers with imagination and character. The record of your work should therefore be such that while it helps the

advancement of your profession it should occupy a high place in public esteem. Your profession has a priceless heritage, and to you is entrusted the charge of public service on which no little skill and care have to be bestowed.

In conclusion let me assure you that it is my sincere wish and prayer that our inspiring ideal, in the words of Tennyson, should be to strive and to work sincerely—

"Till each man, find his own, in all men's good
And all men, work in noble brotherhood,
And ruling by obeying nature's powers
And gathering all the fruits of peace
and Crown'd with all her flowers."

Address delivered by Mr. Mahabir Prasad, B.Sc., M.I.E. (Ind.) at the Nineteenth Annual General Meeting of the United Provinces Centre held at Agra on 26th November 1939.

Gentlemen,

I thank you most sincerely for the honour you have done me in electing me to preside over the United Provinces Centre of the Institution of Engineers (India) in the coming year. It is impossible to convey to you how much I appreciate the honour.

It was towards the end of September that I was informed that I had been elected to preside over this meeting. But I was busy with official duties and I forgot all about the matter till I was reminded by the vigilant Secretary to send my address for printing. I immediately obtained some copies of the Addresses of the former Presidents.

The learning and knowledge set forth in some of the Addresses left me struck with awe. I despaired of submitting anything like it. Then the idea struck me that probably the members will be interested in the every day work in which I was engaged and their advice might help me in my work. This Address was got up in a hurry and I hope the members will excuse me for its short-comings.

We meet to-day in Agra, the city of Akbar and the Home of the immortal Taj situated on the right bank of the Jumna. Agra's natural site and its historical monuments combine to make it a beautiful city. Before all else comes the Taj Mahal, a perpetual source of wonder and inspiration, a perfect realisation of technical art and a lasting memory of an Emperor's love. Then comes the Fort with its variety of styles, its storied palaces, mosques and battlements, the *Machi Bhawan*, the *Shish Mahal*, the *Diwan Khas*, the *Pearl Mosque* with its exquisite tracery and workmanship.

Twenty Miles away from Agra is Fatehpur Sikri. It still speaks eloquently of the great Akbar, Emperor, teacher, visionary, who brought it into being. Its *Buland Darwaza* stands to this day as one of the noblest portals in the world.

MEMBERSHIP OF THE UNITED PROVINCES CENTRE.

Coming to the business of the day the Annual Report has already told us among other things that the number of Members, Associate Members and Students in the United Provinces Centre was 128 in December 1938 and has fallen to 120 due to the various reasons stated by the Secretary in the Annual Report. All Members are requested to try and enrol new members.

In his Presidential Address for 1931, Rai Bahadur Chhuttan Lal said that there was scope for research even when we deal with seemingly unimportant matters in our daily vocation and the field for research is vast and within the reach of most engineers.

My experience is confined to High Ways and Structural Engineering. I set before you some of the experiments that were carried out in this Province and with some of which I was associated.

REINFORCED BRICK CONCRETE (R. B. C.)

For some years past we have used reinforced brick work in this Province. In many cases this form of construction proved cheaper than reinforced cement concrete but it was always felt that reinforced brick work not being homogeneous is not a sound form of construction. In many places, however, the cost of stone is so high that the cost of ordinary reinforced cement concrete becomes prohibitive.

Good over-burnt bricks are available almost everywhere at a reasonable price, and if brick ballast is substituted for stone ballast in the reinforced concrete, we would get a material which, being homogeneous, would be sounder than reinforced brick work and even in some cases, cheaper owing to the fact that the depth can be made whatever is necessary instead of this being governed by brick dimensions.

The Principal, Thomason Civil Engineering College, Roorkee, was asked by the Chief Engineer, Public Works Department, Buildings and Road Branch, to carry out experiments on brick concrete. I was serving as a Professor in the College at the time, and was associated with the experiments which entailed testing to destruction under compression nearly 288 samples in a Buckton Machine. The following conclusions were drawn from the experiments :—

(*i*) It is safe to substitute brick ballast obtained from ordinary well burnt bricks for stone ballast in reinforced work. Care should be taken to exclude all under-burnt and black spongy (Jhama) pieces. Only hard, fully burnt pieces of ballast should be used.

(*ii*) The gauge of the brick ballast should be 1″ to 1½″.

(*iii*) Leaner proportions than 1 : 2 : 4 should not be used for reinforced work.

(*iv*) It is safe to assume a working strength (f_c) of 600 lbs. per square inch in compression. This gives a factor of safety of over 4.

(*v*) The modulus of elasticity (E) may be adopted as 10^6. This gives the value $n=30$.

The value of f_s being 18,000 as usual, the following formulae for depth and reinforcement have been evolved from the above conclusions :—

$$d = \sqrt{\frac{M}{125b}}$$

$$\text{and } A_s = {\cdot}00833 \times b \times d$$

where 'M' is the maximum bending moment
'*d*' is the effective depth.

'A_S' is the area of reinforcement required,
and 'b' is the breadth.

The name given to this material is "Reinforced Brick Concrete."

WHITE ANT EXTERMINATION.

Engineers are often troubled by white ants and various substances have been in the market. I had occasion to try the following proprietary article and found it satisfactory and I am describing the process as it may help other brother engineers.

A new process for the extermination of white ants has recently been introduced into this country. This process which originated in Australia, consists in "Spraying" or "Dusting" over any white ants which can be found, a poison in powder form. The ants thus sprayed return to the nest and convey the poison through the queen ant to the whole of that particular family. Since a building may be affected by ants from several nests situated at different places outside the building, it is necessary in order to ensure that all of these nests are exterminated to spray "Sample" ants from all the different nests around. The method adopted is to see that no white ant tracks are disturbed for several days, thus probably obtaining tracks of ants from all the nests which affect the building. If the building is not very badly attacked, it is wise to place in different positions (particularly where tracks of ants have been observed) pieces of soft wood such as pine or chir so as to attract ants to the spot.

When operations are commenced, *i.e.*, when it is observed that there are numerous tracks in different parts of the building, the operator having filled the "spray gun" with the powder supplied, brushes his hand over the tracks at each place, and having done so and having seen that there are actual ants exposed, sprays these with three or four doses from the gun. The gun blows the powder over the area where ants are seen and some of the powder falls on the ants themselves.

Nothing more is necessary provided every ant track is thus treated and, of course, provided that the tracks which are treated include representative ants from the various nests around the building.

In about 48 hours the powder will have done its work and the ants in all the nests around will be dead. In order to ensure that all the nests have been treated, it is a wise precaution to visit the building again in a week's time, and then if any new tracks are seen, to treat again as before.

It must be realized that the cure is not permanent; it is always possible that new ants may come or that a nest which has not previously attacked the building may begin to do so. All that is necessary is to observe whether any new tracks make their appearance and, if they do, to treat them at once in the manner already described.

This remedy was tried in Sitapur Kutchery and it was observed that in three out of the four affected rooms, the ants disappeared after the first application while in the fourth room (double lock room) four applications were required before the desired result was achieved.

The powder which is called "Virus" is obtainable from Messrs. R. E. Bury, Mechanical Engineers, 25 Outram Road, Lucknow, at Rs. 19/8 per lb. tin with a blower and full instructions. It is also available in $\frac{1}{4}$ lb. tins at Rs. 6/8 per tin including outfit. The cost of using the powder is not great; for one application about 1/10th of an ounce is required and this costs about -/2/-.

COLOURING PLAIN GREY CEMENT SURFACES.

I describe below a method by which the colour of cement surfaces can be changed by painting with a slurry of coloured cements.

The paint is made by mixing any coloured cement with Sealocrete Normal Rapid-Hardening Premix Solution and water and is well fitted for reviving old cement surfaces. It can be applied to new or old cement walls treated to any colour by using coloured cements. Sealocrete Normal Rapid-Hardening Premix Solution is a product of Messrs. Sealocrete Products Ltd., 45/50 Holborn Viaduct, London, E. C. 1. and is obtainable through Messrs. N. D. Radhakishen & Sons, Rawalpindi, @ 10/6 per gall. in 1 gall. tins and 7/6 per gall. in 5 gall. tins.

This paint is not suited for lime washed surfaces.

New surface can be treated while still damp and water percolating through.

Old surface should be well brushed and cleaned of all dirt and impurities. Greasy and smooth spots should be well rubbed with steel brushes so as to open the pores. Surface should be well watered and thoroughly damped before applying the paint. The paint is applied like an ordinary paint or distemper with brush.

Second coat should be given after 12 hours.

PAINT INGREDIENTS.

Add 1 part of Sealocrete Normal Rapid Hardening Premix Solution to 4 parts of water; *stir well;* then mix 5 parts (by measure) of coloured cement as required, stir well into a slurry, and apply, stirring at intervals like ordinary wash.

All brushes and utensils should be thoroughly cleaned after use immediately.

COVERING CAPACITY.

1½ gall. Premix Solution in proportion of 4 parts water and 1 part Premix with 1 Cwt. bag of cement will cover about 160 square yards in two coats.

SWEATING OF CEMENT CONCRETE FLOORS.

In some of the cement concrete floors that I laid I had trouble due to sweating specially during rains. The floors I had made were of 1" concrete of proportions of 1 : 2 : 4 over 3" lime concrete.

In the cement floors made in the rooms of Fyzabad Inspection Bungalow in 1928, twenty per cent of well slaked white lime was used with cement and it was found that the floors did not sweat.

I shall be thankful if other Engineers will let me know if they have been able to get over the difficulty and if so in what way.

CEMENT CONCRETE FOR ROAD WORK.

It is generally considered that cement concrete roads are expensive and so are not practical politics.

It is however found that in certain cases a cement concrete surface will be cheaper in the long run, though it may be more expensive in first coats.

If the rate of *kankar* is Rs. 10/- per cent Cft., Rs. 2 per cent is cost of consolidation and the life of the mile be three years, it is found that the cost of maintenance works out to Rs. 1,143/- per year as detailed below :—

COST OF RENEWAL.

		Rs.
Kankar 24,000 Cft. @ (10+2=12%)	..	2,880
Patries	..	100
		2,980

COST OF MAINTENANCE

		Rs.
Annual cost 2,980/3=993		
P. R. metal 600 Cft. at 10/- ..	..	60
Labour 1/12 mate at Rs. 12/- p.m.	..	84
2/3 *Beldar* at Rs. 9/- p.m.	..	
Sundries	..	6
		150

Total 993+150=1,143

Assuming the cost of cement concrete 3" at Rs. 2/- per square yard as computed for Cawnpore division. As shown below the cost of maintenance of 3" cement concrete mile will work out to Rs. 1,240/- per year as shown below :—

		Rs.
Cost of concrete 7040 × Rs. 2/- ..	..	14,080
Patries	..	100
		14,180

Maintenance Labour—66 .. } = 1247
Annual cost 14,180/12+66 .. }

It will thus be seen that assuming a life of 12 years for the 3" cement concrete slab the cement concrete mile will be hardly more expensive to maintain than a *Kankar* Mile, and will be dustless and superior to a *Kankar* Surface.

COMPOSITE CEMENT CONCRETE

I describe below an experiment on making economical cement concrete road slabs :—

I have given above the results of experiments which show that over-burnt brick ballast is a good substitute for stone ballast. The following experiments consist in giving a layer of stone ballast over a concrete of brick ballast.

A trial length of 460′ was laid in furlong 3 of mile 56 of Lucknow-Jhansi Road. The width was 12′.

Sub-Grade.—Was old stone waterbound macadam dug up re-graded and re-rolled, with new stone metal to correct camber grade and alignment.

Cement Concrete Slab.—This was laid in two layers. The bottom consisted of cement, ganges sand and over-burnt brick ballast in the ratio of 1 : 8 : 16 and was laid 4″ thick at the edges and 3″ thick in the centre. The second layer was of cement. Badausa sand and Tamalaya 1″ to 1½″ stone ballast in the ratio of 1 : 2 : 4 and laid 3″ thick at the edges and 2″ thick in the centre.

Laying and Curing.—The slabs were laid on the alternate bay system in lengths of 33′ with a width of 12′. The joints were plain butt joints and were rounded off. Within three hours of the laying of the bottom layer the top layer was laid after roughening the surface of the bottom layer. All the concrete was mixed in a cement concrete mixer. The top concrete was kept wet for fourteen days after which period Silicate of Soda diluted with water in the ratio of 1 : 5, was applied in three coats on three consecutive days.

The total cost including side forms and service road came to Rs. 3/- per square yard.

The work of laying cement concrete was done in January, 1935. The surface to date is wearing well and there are no signs of cracks or any flaws.

If both the slabs had been made with the usual mixture of 1 : 2 : 4, with stone, the cost would have been Rs. 4/- per square yard.

Experiments are at present being made in the Buildings and Roads of this province, which, if successful, will make cement concrete roads cheap in first costs also. It consists of making the road slabs of 3″ thickness only, the lower slab being of brick ballast 1½″ thick, topped by cement concrete of stone 1½″ thick.

It is found that a 4½″ coat of stone metal, painted with tar No. 2 as first coat and asphalt as a second coat cost Re. 1/10/- per square yard.

It is also found that a 3" slab of uniform thickness of stone ballast of $1\frac{1}{2}$" gauge laid in proportion of 1 : 2 : 4, cost Rs. 2/- to Rs. 2/2/- per square yard.

If however the 3" slab is laid as a composite coat of stone ballast, the top coat being of stone ballast $1\frac{1}{2}$" thick in proportion of 1 : 2 : 4 and the bottom coat to be brick ballast $1\frac{1}{2}$" gauge in proportion of 1: 3: 5, the coat will be Re. 1/11 per square yard.

Experiments are at present being made on a small scale to see how far the 3" composite slab will actually stand upto traffic in situations where the roads are surface painted. Whether the results will be actually satisfactory or not it is too early to say.

CONCLUSION.

In describing the above every day experiments and experiences my object is to suggest to all Engineers to carry out experiments.

It does not fall to the lot of every engineer to be entrusted with the design or the execution of a Taj Mahal but all of us can experiment in our every day work in a small way and make matters easier for ourselves and for those that come after us.

Complaints are often heard that papers for the Institution meetings are not forthcoming in sufficiently large numbers. Members say that they are busy in doing their routine duties and do not find time.

I would submit that every engineer finds difficulties in his every day work and he gets over them. If they will write brief notes on such matters, such papers will be useful to others.

All of us do construction and repair works every year, probably put up new buildings or construct bridges. If members will write notes on what they have done they will make instructive and interesting reading.

Such papers will remain as foot-prints in the words of the well-known poem which says :—

Foot prints that perhaps another
Sailing over life's solemn main
A forlorn and shipwrecked brother
Seeing shall take heart again.

I remember to have seen full details of the Agra Water Works and the Sarda Canal in the minutes of the Institution of Engineers, England. I suggest that our Members may also write papers on works with which they are associated.

I hope that the simple experiences described by me may encourage others to do the same.

Gentlemen, I thank you again for electing me to be Chairman for the coming year.

DISCUSSION ON MR. A. VASUDEVAN'S PAPER ON MODERN TENDENCIES IN DESIGN AND CONSTRUCTION OF TRACK.

(*This paper was published in Journal Vol. XIX, Part II, pp. 1-82*)

Mr. A. C. Austin: My remarks are confined to the theoretical side of the determination of track stresses. In this direction Mr. Vasudevan's excellent paper is more than tantalising. He leads us blindly through a forest of mathematical formulae and just when we think that we are safely at the end of the journey, he leaves us to find our way across an uncharted marsh.

To be more precise he tells us exactly how to take out the stress in rails under static loads but offers us little more than vague clues as to how we are to deal with the dynamic considerations. The speed factor which has for many years been accepted by the Standards Office is $\frac{V}{3\sqrt{n}}$. This at high speeds gives a figure as great as 0·6. The author, however, is content to refer us lightheartedly to Dr. Wasintynski's figures of 7—14% without giving any opinion as to whether we should accept them. Like Mr. Asquith he says " 'Wait and see.' Some day the Standards Office will tell you."

The author does tell us, however, that we must add something in the nature of 50% for side thrust. Let us examine where all these figures are leading us.

In item 30 of a set of figures tabulated by the Standards Office some years ago, we find a calculated stress of 21·55 tons per sq. inch set up in the rails by an engine running at 55 miles per hour. This allows for speed and out of balance but not for side thrust. Would the author have us add yet another 50% to 21·55? If so, the stress works out to somewhere about 32 tons per sq. inch!

Would the author have us believe that such stress actually occur?

Mr. A. N. Bose: In page 19, line 18 (from top), the author writes that the 'joint gap....is independent of the length of the rail after a certain *minimum* length of rail has been reached.' I suppose he means "maximum" not "minimum." It will be interesting to learn what this maximum is.

I think, with rails of light section there may be some risk of buckling in the middle, *i.e.*, if the section is not strong enough to withstand this laterally. Can the author give us some information about the lightest rails, which have been welded together with success?

In page 31, clause 10, the author says that heavier axle loads may be allowed on welded rails; but in page 27, line 28 (from top) he says that welding impairs the strength and efficiency of the rail as a whole. I do not know how to compromise the two statements.

Mr. N. K. Roy: As a collection of data regarding the loads a particular permanent way is designed to carry, methods and effects of these loads on the component parts of the designed track, and lastly the nature and dimensions of these component parts, Mr. Vasudevan's paper is an excellent one.

The main point of interest raised in the paper is the length of rails and welding of rails. Rail joints are the weakest points of a track and Engineers are now trying to reduce the number of joints by :—

(i) increasing rail lengths rolled,
(ii) welding rail joints.

The author has mentioned three difficulties in the way of using very long rails, namely :—

(a) limited capacity of the rolling mills producing rails,
(b) limitation of the means of transport of long rails,
(c) width of rail joint gap to be provided for rail expansion under temperature change.

It has been explained by the author that none of these difficulties were unsurmountable. The author however does not mention the most practical difficulty of using very long rails, pre-welded or unwelded, in India where loading, unloading and track laying is almost always done by manual labour. Mechanical devices in the hands of our untrained labour will be wastage of time and labour.

As regards welding, the Indian Railways cannot be interested in any process that does not do the work at site, due to reasons stated in the concluding portion of the previous paragraph and also due to transport difficulties in carrying 1/3, 1/2 or one mile long pre-welded rails.

The percentage of failure of welded rail joints, according to the author, has been found to be very small but it will be interesting to know how a suddenly discovered failure will be tackled quickly as it is only reasonable to assume that the plants will be at the headquarters.

According to the author the cost of welding a rail joint is 1·5 to 13 times the cost of an ordinary fish-plated joint, but inspite of this he expects a return of not less than 100% on the capital spent in welding joints. This return according to the author will accrue from :—

(i) Saving in labour of maintaining joints.

No doubt the joints are the most difficult portions of track to maintain but the Indian Railways are quite efficiently maintaining their track with 2 to $2\frac{1}{2}$ men per mile of B.G. and $1\frac{1}{2}$ to 2 men per mile of M.G. track. It is no use comparing this strength with those of English or continental Railways. The capacity of labour and the conditions of maintenance are totally different. It is very doubtful, if, even with welded rail joints it will be possible to reduce the gang strength any further, taking into consideration the efficiency of Indian labour, the climatic condition, nature of sub-grade, etc. The services of the keyman can never be dispensed with. Consumption of ballast, sleepers and spikes will remain unchanged and the percentage of failure of fish-plated joints will never be more than the failure of welded joints.

(ii) Longer life of rail due to elimination of joint batter.

The present standard of Indian Railways for B.G. is 90 lbs. B.S.R. and for M.G. 60 lbs. B.S.R. and it is not known for how many years these standards will be adhered to. The Railway Engineers know that relaying of track is very seldom necessitated by hogging of rail joints or by the full wear of rail section. It is very often controlled by other factors such as

introduction of heavier axle load, change in standard, requirements of branch lines and sidings. Rails released from main line is very often used in branch lines or sidings and it is doubtful if the 'total' life of rails will be increased by welding.

(iii) Labour saving in laying rails due to increased life.

It will be very difficult to take out welded rails from the track at the time of relaying and loading them in trucks. If these are cut into shorter pieces by oxy-acetylene or other processes, this will add to the cost of dismantling. Thus it will be found that even if it is admitted that relaying of welded track will be required at longer intervals than unwelded track, the extra expenditure incurred in dismantling and laying welded track at longer intervals will not be less than the expenditure involved in dismantling and laying unwelded track at more frequent intervals.

(iv) Better conductivity in track circuits and the elimination of the necessity for provisions of battered joints.

The total length of track-circuited portion of the track is so negligible in comparison with the total length of track without track circuiting that this point is not important.

(v) Saving in maintenance of rolling stock and motor power.

The expected saving is only indirect and may not be realised in practice.

(vi) Riding comfort as a result of smoother and evener track.

There is hardly any economic aspect of this factor.

(vii) Saving in maintenance of alignment and surface by practical elimination of creep and its effects.

It is not clear why creep will be totally eliminated from track laid with welded joints.

(viii) Less dislocation of or interference to traffic due to less frequent renewals.

(ix) Rail ends and rails of different lengths can be used.

This probably applies to laying of second hand rails only as it is reasonable to assume that new rails will be rolled to certain standard lengths.

(x) Heavier axle loads and greater speeds can be permitted.

The rail section fit for carrying a certain axle load at a certain maximum speed is much heavier than that arrived at by theoretical calculations and so it is doubtful if welding of joints will help carrying greater axle load.

It would have been very useful if the author would have given us some comparative ideas of maintenance cost of the same or similar portion of track before and after welding of rail joints. Indian Railways have evolved quite a strong and economical standard of track for carrying the load they are asked to do and Indian labour is quite efficiently maintaining it at a very reasonable cost. Before introducing welded joints, extensive tests should be made on different Railways and data collected. It will be interesting to know the results of welding joints on E. I., N. W. and G. I. P. Railways.

The author has discussed a few important points regarding sleepers and other permanent way fittings :—

(i) Sleepers.

Taking every thing into consideration a hard wood sleeper is probably the best. The problem however is not whether wooden sleepers are better or more economical than steel or C.I. sleepers but whether Indian forests can meet the demands of Indian Railways. Sal, the king of Indian hard wood, takes at least fifty years to mature and indiscriminate de-forestation in the past has made the situation worse. India is a vast country with excellent forest resources and with planned a-forestation it should be possible to supply the full quantity of sleepers required by Indian Railways.

On page 52 the author has mentioned of using 'cuts' between full sleepers. In a 36′ rail, say, according to the author, 10 full sleepers and 7 cut pieces were used, whereas for main line traffic, probably 15 full sleepers would have been required. It will be interesting to know the sizes of these cut pieces and also if 10 sleepers were found sufficient to maintain gauge.

(ii) Fish-plates.

The B. N. Railway type of fish-plates with thicker centre is another instance of a good thing creating practical difficulties. The inside and outside plates are different and the fish bolts

are of different lengths. The illiterate keymen indiscriminately used the other plate for inside and *vice versa*. A few failures at the plane of varying thickness were also noticed.

(iii) Spikes.

On the Eastern Bengal Railway only four spikes on the straight and six spikes on the curves are used. This arrangement has been found to be quite satisfactory and it is difficult to understand why more spikes should be necessary under ordinary circumstances.

Track laying is very often done with the help of mechanical devices in foreign countries but in India it is almost always done by manual labour. Though conditions are quite different it will be interesting to know the cost of laying and relaying in different countries.

Finally it will be noticed that these criticisms have been mainly directed to the financial aspects of track design and maintenance. The author is to be congratulated for his labour in collecting many useful data in one place which will convince our brethren in other branches of the profession that the Railway Engineers in India are not lagging behind their colleagues of other countries and that they are ever alert in carrying passenger and goods safely and economically. Our aims and objects however should not be to become as modern as other countries but as modern as our country wants us to be or rather, our country can afford to be.

Mr. W. B. Burford : The title of the paper which we are to discuss this evening is Modern Tendencies in Design & Construction of track. This is a large subject on which a whole book might easily be written, but the author of the paper has given us a very comprehensive view of the subject in the space at his disposal.

About one hundred items have been dealt with in the paper and a committee of tract experts could spend a whole day in the discussion of only a few of them.

For the purpose of general discussion by the members of the Bombay Branch of the Institution, it will be sufficient therefore to make a brief review of the paper as a whole and then to consider one or two points on which an Engineer, who is not a Railwayman, can form an opinion.

The introduction to the paper refers to the loss of transportation monopoly and to economic depression as the main causes for the recent progress in the design and construction of railway track.

The results are stated to have been increases in the weight and capacity of rolling stock and in the number of speed of trains. It is interesting to consider in what way such increases can improve the situation and whether they are essentially remedial.

It is also of special interest to note the extent to which such changes have taken place in this country during the past five years.

The object of increasing the size of goods vehicles is to reduce the wagon mileage for a given volume of traffic but this result can only be obtained if the average load per wagon is increased at the same time.

It also has the possibility of limiting train lengths to what can be handled in existing goods yards and at the same time increasing the load per train and consequently the ton miles per engine hour.

In this country, in spite of the number of 20 ton and even 40 ton wagons available we find that the "average wagon load during the run" in 1937-38 was only 12·9 tons and that the increase in this figure since 1932-33 was only 0·6 ton. This state of affairs is due to the large proportion of smalls and also to the urge for giving quick delivery in preference to holding wagons for obtaining further loads.

In other countries this difficulty has been met to some extent by the introduction of the container system but although the possibilities of this system in India have been investigated it has not yet been found to be an economic proposition mostly on account of the lack of suitable goods for back loading.

Until the loading of the wagons already in use has been increased there is no need for a general increase in wagon capacity, and until the average weight of wagons is increased, there is no need to increase the weight of the engines except for obtaining increases in speed, as the existing locomotives are already hauling loads which are limited by the siding accommodation.

The figures for India for the years already referred to are :—

	1932-33		1932-38	
Average weight of steam train, goods (including engine)	917	&	945	tons.
Ditto excluding engine	803	&	835	tons.

From this it appears that the average weight of steam engines has fallen from 114 tons to 110 tons and has not increased.

Average weight of electric train, goods (including loco.) ..	1117	&	1143	Tons.
Ditto excluding loco. ..	978	&	1005	,,

The average weight of the electric locomotives has remained constant.

The average numbers of goods wagons per train on the main lines in these years were 51 and 52 for steam trains and 52 and 54 for electric trains. The reason for the average weight per train increasing by a larger proportion than the number of wagons is a combination of the better wagon loading with the variation in the proportion of loaded wagons to the total, the figures for which were 68·9 and 67·5 for steam worked trains and 83·6 and 79·9 for electrically worked trains.

With slightly heavier trains and the same or less weight of engine, the running speed is not likely to increase, and any reduction in time from start to destination can only be obtained by better locomotive efficiency and by better operating.

The loads and speeds of passenger trains are controlled by various factors such as the comfort and convenience of passengers and in this country we have not yet any trains scheduled at "well over a hundred miles to the hour." There is tendency however towards higher speeds and even if this is not sufficient to affect track design and construction *per se*; there is a constant effort to obtain greater comfort.

The question of improving the existing track locally so as to make it fit for higher speeds than have previously been worked to, is another matter, and this does not offer any particular scope for improved designs or for more modern methods of

construction. Thus in India, at present, it is still more true than it may be in some other countries that, in the words of the author, "Modernising permanent way has become primarily an economic problem."

With this consideration in mind we can now turn to the paper itself and confine our discussion mainly to the economic point of view.

The investigations which have been made into the problem of track stresses may have the effect of justifying the retention of existing track for longer periods and also enable replacements to be made with lighter or better designed material. It was once said that a certain impact formula was good enough because a failure had never been known to occur in cases to which this formula had been applied but this attitude is not one which leads to a maximum of economy in design.

The master diagram which has been evolved as the result of much endeavour is obviously a valuable aid in this direction.

In considering the stresses in sleepers the author gives the ballast co-efficient in terms of $Kgms/Cm^3$, but in this country it is more usefully expressed in lbs/in^3 and the equivalent figures are 181 lb/in^3 and 469 lbs/in^3. There appear to be some printing errors in the equations which are given in connection with track stresses but these will no doubt be corrected in due course.

In the section stresses in fish-plates the author mentions that tightening up of fish bolts increases the bending moment in the fish-plates and avoids battering action at the rail ends. It follows of course that slack fish bolts have the effect of increasing the battering no less than rigidity of the supporting sleepers on either side of the joint which the author mentions as a cause of battered rail ends.

This subject is however referred to again in Chapter II of the paper which deals with rails and fish-plates. It is stated that rails and rail joints have been dealt with first as they form by far the most important track components and account for more than 30—40% of the total cost of the track. Sleepers and their fittings are considered next after which formation, lay-out, ballast etc. are considered. It is open to question whether

this is the correct order of importance since with a bad formation and unsuitable ballast, the best of track materials can be quickly ruined and would fail to provide a good road no matter how well designed.

From the point of view of a practical maintenance supervisor the secret of good track is drainage, more drainage and again more drainage.

However, to return to rails—the author again mentions increasing axle loads and speeds but apart from the question of stresses it is only natural that an effort should be made to obtain rails that will last longer.

The weights of rails used in India are given as 90 lb. N.W.R. 100 lb. G.I.P.R. and 115 lb. E.I.R. and apart from the inclusion of the Indian Standard weights of 75 lb., 90 lb. and 115 lb. for B.G. track, this is apt to be misleading as the G.I.P., for instance, has besides 100 lb. rails considerable mileages of 69 lb., 80 lb., 82 lb. and 90 lb. track as well as about 2 miles of 115 lb. track near Khandala and some other sections in various parts of the system.

The statement is made that the strength of a track increases rapidly as the weight of the rail increases and it may be presumed that the author implies a given section of rail ; a flat footed rail may be stronge than a B.H. or D.H. rail of the same weight.

Further on the author says that the wisdom of replacing with heavier rails has been amply rewarded by the reduction in the number of breakages and it would be interesting to know how much money has been spent on this justification and how many breakages per mile per annum were being experienced before the replacement was made.

A breakage is not necessarily a sign that the rail section is too weak and the money might perhaps have been better spent on a Sperry rail fault detector.

An analysis of rail fractures on Indian Railway would make an interesting appendix to the paper.

Our attention is directed to the importance of seeing that the vibrations due to rail joints do not synchronise with the individual vibrations set up in the rolling stock itself. Perhaps vertical oscillations would be a better expression and it would be

interesting to know the limits of the periodicity of normal rolling stock and how this corresponds to rails of various lengths with trains travelling at various speeds.

The author has devoted thirteen pages of his paper to the welding of rails and the subject could not doubt be discussed at great length. As our time is limited, a few comments only will have to suffice. It is not quite clear from the references on pages 19 & 21 whether the 1,482 ft. rails of the Delawar & Hudson Rail Road were rolled that length or were welded before transportation, but on page 26 it appears that this Railway transported rails, 1,498 ft. long which had been resistance welded. If this is correct, it would be interesting to know how it was *not* found to be more economical to weld the joints at site. It would also be interesting to know how the Egyptian Railways were able to justify the welding of rails in sidings where speeds are low and most of the inherent advantages are lost.

When the fusion method of welding is being used, it would appear to be better to remove the blow lamp before igniting the mixture in the crucible as it is not very safe to go close to spluttering molten metal and the rail ends would not cool down very much in the few seconds which are necessary for the process of combustion.

With regard to the thermit welding processes it will be interesting to see from experiments in this country whether fusion welding of both high and ordinary carbon rails is as successful as the combined process.

In concluding his paragraphs on the length of welded rails the author mentions that some engineers pin their hopes to a joint yet to be evolved that is able to deal with considerable changes in length, but as the welded rails are found not to expand any more than rails of normal length, the necessity for such a joint is not apparent. This subject was discussed at some length at the Paris Meeting of the I.R.C.A. in 1937 and a resumé of their conclusions would form a useful adjunct to this paper. The general consensus of opinion at that time was in favour of welding rails up to a length of about 260 ft. and not more except perhaps in tunnels.

The cost of welding rail joints is stated to vary between wide limits in other countries, but in India it has been found

that fusion welding can be done at site for about Rs. 40/- per joint or under according to quantity and a pair of fish-plates with bolts and bonds cost about Rs. 8/8/- including fitting.

It is stated that the Delawar Hudson is the only Rail Road which has a specification for rail welding and it would have been interesting if permission could have been obtained to attach a copy of this specification to the paper as an appendix.

A reference might also be made to the Symposium of Welding published by the Iron & Steel Institute.

In summarising the advantages of welding rail joints the author includes heavier axle loads and greater speeds, but it has previously been noted that the remaining joints still remain the limiting factor as regards strength. A practical disadvantage which has not been mentioned is that of turning the rails when they have reached the limit of wear on the running face.

In summing up the defects and difficulties the author concludes that welded rail joints will find universal application in the near future but even if the advantages outweigh the defects, it still remains to obtain an economic justification and this depends on the cost at which rail joints can be welded either at site or in a depot. The author selects the combined process for purposes of immediate experimenting but if the fusion process is found satisfactory, there appears to be no reason why this should not be used so as to reduce the cost.

The experimental welding on Indian Railways, which the author mentions, has now been concluded and up to date the results have been satisfactory.

A note on this work has appeared in the Press and an essay on the subject would be an interesting supplement to this portion of Mr. Vasudevan's paper.

In considering the manufacture of rails the author again mentions increasing loads and speeds, but he does not mention what is perhaps a more prevalent factor—namely the constant war between locomotive and permanent way engineers. The former naturally want their wheel tyres to last as long as possible and the latter have to keep pace with them as best they may.

The idea of putting a reverse camber into rails is all very well in its way, but it introduces a difficulty when such rails are

to be welded into longer lengths as the ends are not quite parallel and there is likely to be either a permanent bump or a fracture of the weld if something is not done about it.

The paragraph on processes of manufacture states that four of these are permitted under the Indian Railway Standard Specification, but it would be interesting to know which process is most used in the manufacture of rails by Tatas.

We now return to the subject of rail joints and the remark made by the author under the heading "Stresses in fish plates" that "when the maximum bending moment in a fish plate is small it indicates that the sleepers nearest the joint are supporting the wheel load at the joint, a feature which is not at all desirable as it produces battered rails." This wording is not as clear it might be, as it seems to imply that it is a fault in track maintenance to have the joint sleepers well packed, whereas in practice the fault is usually in the opposite direction.

This question of "the yielding of the ballast, the stiffness of the rail, wheel loads, speed and lack of continuity at the rail joint" has recently been dealt with by Prof. C. E. Inglis in a paper on "The Vertical Path of a wheel moving along a Railway track" published in Vol. II, No. 5 of the Proceedings of the Institution of Civil Engineers of March 1939 and reviewed in the *Railway Gazette* dated 5-5-39.

In this paper it is stated that at slow speeds the vertical movement at a joint is greater when the ballast is less yielding (and conversely in the rail itself), but that at higher speeds the vertical movement may in any case actually be less. What is good for the joint may however be bad for the rail.

With yielding ballast the rail undulations are less pronounced than with a less compressible support, but in the former case there is a much greater chance of such undulations becoming amplified at critical speeds. The closer spacing of sleepers at the joints reduces this tendency.

The review of this paper suggests that "a general and also considerable increase in weight of rails seems to be a rather expensive method of dealing with the problem" of vertical movement in rails and at joints, and that the design of an efficient joint is still felt to be the most economical solution.

We can pass over the chapter on sleepers except for noting the remark that "the considerations determining the choice of the type of sleeper used are technical, local and economical." In working out an example of the economics of using steel or wooden sleepers, vide Chapter VIII, the author concludes that, because the yearly costs work out to Rs. 20/- per mile cheaper in one case than the other, the choice should be in favour of the cheaper type. This is rather a sweeping conclusion when the difference is only just over 1% and when an additional half year in the assumed life of wooden sleepers would tilt the balance to the other side. The fate of the forest industry should not be made to depend on so small a margin. The idea of using a more nearly square section of wooden sleeper in this country was one which would no doubt have affected the industry if it had been finally adopted, and the ability of the local market to meet requirements must, in such cases, be considered as a factor in arriving at a decision.

In Chapter IV the author comes to the consideration of track formation and ballast. It would be interesting to know if the French idea of laying a waterproof covering over the formation would be a satisfactory and economic solution of the difficulties caused in this country by black cotton soil on which considerable sums have sometimes to be spent. The chances are that such a carpet would soon break up and would not last long without some sort of reinforcement. A layer of old sleepers laid herring bone pattern with or without ashes on top have been tried with some success, but ashes alone are cheaper and possibly almost as effective. The English plan of putting down an under layer of big sized ballast 3″ to 8″ in diameter would not work in soft spots as the heavy stones would simply be swallowed by soft soil and over black cotton soil even the usual 2 ft. layer of moorum would probably fail to keep the ballast layer intact. On firmer formations the layer of big ballast might perhaps be adopted with advantage.

It is interesting to note that some Railways on the Continent ram or roll the ballast before laying the permanent way as there is a difference of opinion as to whether a road bed should be disturbed or not when complete renewals of track are being carried out.

Apart from increases in loads and speeds there is a natural tendency to improve layout as opportunity offers, as for instance, when the tongue rails of a switch can be replaced by longer ones or when the angle of a crossing can be eased. The elimination of curves of contrary flexure, whenever possible, is another natural improvement. The author states that "really high speeds are possible only with curves which do not require gauge slackening or widening, for the amplitude of hunting increases with disastrous effect on both the rolling stock as well as the track." On curves of a certain sharpness it has been customary to lay the rails to gauge with a view to reducing rail wear and tractive effort and in the hope that the gauge would not widen itself any further. The present tendency seems to be to discontinue this practice as it was found that the track resistance was not appreciably reduced, but it is doubtful whether a tendency towards hunting on such curves had anything to do with such a decision.

Under the heading of super-elevation it is stated that "no cant is given to curves in turnouts" but it would perhaps be more correct to say that cant is given in turnouts to the extent permitted by the local conditions and when sufficient cant cannot be introduced, a speed restriction over the turnout has to be imposed. The author returns to this question in the next Chapter.

In the chapter on construction of track the author mentions some mechanical appliances, but as far as this country is concerned, it is usually found difficult to justify these on an economic basis only. Wooden sleepers are usually adzed, bored and chaired by machine, and one plant can turn out 400-500 sleepers per day. In this case accuracy is also an important consideration.

With reference to the modernizing of existing track, whether heavier loads are to be worked at higher speeds or not, it is always necessary to consider all possible and economical means of increasing safety, reducing the wear and tear due to impact and maintaining the track in perfect condition. The policy of gradualness in the strengthening of track has its limitations and a lot of expense can sometimes be saved by making a reasonable forecast of the demands which may have to be met during a fairly long period. On the other hand it is no doubt unfortunately true that in some cases money has been spent

unnecessarily through an excess of optimism. The steps to which most attention has been paid in this country are probably more or less as follows :—

(1) Relaying with heavier track.

(2) Increasing the length of rails.

(3) Improving drainage.

(4) Regrading.

(5) Re-aligning curves.

(6) Introducing transition curves.

(7) Better design of points & crossings.

(8) Use of steel sleepers in crossings.

(9) Welding.

Although the increase of weights and speeds has been mentioned in the introduction to this paper as one of the factors influencing the design and construction of modern track, it is stated in the last chapter that no expenditure can be incurred unless the annual costs are balanced by the annual savings. This is rather a sweeping statement since the factors of necessity and safety have also to be taken into account. The position is more correctly stated further on when it is explained how a choice should be made between "two different types of equipment capable of rendering the required service."

The pitfalls inherent in this process owing to the assumptions which have to be made, have already been mentioned. Another very variable factor, besides the assumed life of material, is its scrap value.

Example I has already been dealt with. In both examples the rate of interest has been taken at the same value as the rate of amortization, whereas it should be more. In these days also interest at 6 per cent is hard to get.

In spite of our criticism this is a useful paper as it gives a good general idea of the problems with which railway engineers have to contend in dealing with the question of track.

Appendix to Mr. Burford's remarks.

In his recent paper read before the Institution of Civil Engineers, on "The Vertical Path of a Wheel Moving along a Railway Track," Professor C. E. Inglis has added another chapter to his extensive work on oscillations of various types. In this case the object was to study the manner in which the running of an axle and a pair of wheels along a straight track is affected by elastic yielding of ballast, the stiffness of the rail, wheel loads, speed, and the lack of continuity at the rail joint. Calculations and experiments show that at slow speeds the more yielding the ballast the less is the vertical movement of the wheel for a continuous rail, but at a joint the reverse applies. It is interesting to note that at high speeds the downward movement at a joint may be less than when the wheel velocity is smaller, due to the downward motion having a limited acceleration depending on that due to gravity and the power of the springs. The load on the sleeper just beyond the joint, however, is greatly increased and accelerations as high as ten times that due to gravity may be obtained on an unyielding foundation, and slightly less with an ordinary good bottom.

The author shows that a wheel travelling along a continuous rail with uniformly spaced sleepers develops a slight undulatory movement due to the alternating hard and soft spots at and between the sleepers respectively. With very yielding ballast, the movement is not so marked but there is a critical speed, well within normal ranges, at which the motion will be considerably amplified. On the other hand, with exceptionally incompressible ballast the general smoothness will not be so good, but the critical speed will seldom, if ever be attained under normal working conditions. It is suggested that with the present practice of varying the sleeper spacing near the joints, synchronism is not likely to be obtained. Professor Inglis points out that vertical movement at joints and in the middle of rails is greatly reduced when heavier rails are used, and shows comparative results for the British Standard 95 lb. bull-head rail with a moment of inertia of 36 in.^{4} units and a much stiffer, hypothetical rail having a moment of inertia of 72 in.^{4} units. The paper shows that the most serious vertical results are obtained at joints. A general and also considerable increase in weight of rails seems to be a rather expensive method of dealing with the problem and we feel that the design of an efficient

joint is still the most economical solution, although it has taxed the ingenuity of engineers for many years. A little more information about the ballasts considered would be useful. The figures given by Professor Inglis to denote the ballast resistance would be more appreciated from a practical point of view if he could state how they vary with usual types of stone and the depth of ballast adopted. The depth is very important, especially when considering the distribution of the load on soft foundations.

Mr. R. K. Nariman regretted that having misplaced his copy of the paper, he had not read it. But after the very lucid interpretation of the paper by Mr. Burford, he was tempted to ask a few questions. One of the difficulties that railways appeared to suffer from, was the haulage of large numbers of empties. Recently he learnt that the B.B. & C.I.Rly. had started leasing out their wagons between Hissar and Delhi for a fixed amount, irrespective of the character of the articles carried. This was a departure from the old rule of charging traffic what it could bear. Mr. Nariman asked whether it would not be practicable to lease out wagons not only from stations to stations—in this case Hissar to Delhi—but also for the return journey, leaving it to the consignors to find the return freight.

Again the through speed of goods trains was reduced and engine power wasted at small wayside stations, where the goods trains were halted for long periods to load and/or unload a few maunds of miscellaneous goods. He asked whether it would not quicken up traffic, if the station staff loaded such miscellaneous goods direct on the trucks, the merchants advised that such wagons would be dispatched on fixed days say twice or thrice a week, and that similarly wagons would be unloaded twice or thrice a week, the goods trains passing through on the remaining days. The wagons from such wayside stations would be taken to the nearest large station or junction, their contents sorted and put in the through wagons for their destination.

The Government were reported to be considering the desirability of taking up some of the non-paying branches. In some parts, the broad and the metre gauge tracks ran side by side for long distances. He had in mind the length Bhatinda-Katkopura. He asked whether it would not save in maintenance if in such cases, the less busy lines were taken up. In this particular case, it might be argued that the metre gauge was required

to feed the Katkopura-Fazilka branch. Even so, probably it would pay to convert the Fazilka-Katkopura to broad gauge and to take up the Bhatinda-Katkopura a metre gauge section. He believed that there were several similar sections in South India requiring consideration.

He understood that the only heavy gradient electrification in India was the Bombay Ghat section of the G.I.P. Rly. He would like to know if this hill section was worked on the regenerative braking system. To one unacquainted with the system, it appeared to be suitable for such working.

It was understood that in some recent accidents on the E.I.Rly. the derailments were due to deliberate removal of fish-plates. Welding of rails and the consequent *diminution* of joints and fish-plates might reduce this risk to some extent.

He wanted to know the effects of long lengths of welded rails had on creeps.

It would be interesting to know also the result of the experiments to support the ends of the rails by short length of longitudinal sleepers.

Referring to the electrification of railways he enquired whether the electric locomotive was found to be less destructive to the rails, as claimed by some, and if any complaints of corrosion of adjoining public utility pipes etc. from stray currents was received in the urban electrified areas.

In some parts he had found it difficult to keep track clear of blown sand and he would like to know the steps taken to reduce the danger and danger due to the accumulation of sand on the tracks.

Mr. J. Ganguly : In page 32 the author has mentioned that welding will be done in E. I., G. I. P. & N. W. Railways but I may mention that welding has been done successfully in Burma Railways—an article on this had appeared in "Welding" in its December 1938 issue. On perusal of the article it is found that not only rails had been welded successfully and the line is standing the severest test but points and crossings had been successfully welded.

The Author (in reply) : Mr. Austin desires to know if I recommend Dr. Wasintynski's figures of 7—14 per cent for

increase in stress due to speed effect. My answer is yes, and I might also add that the Central Standards Office experiments corroborate these figures.

He accuses me of recommending a figure of 50% for increase in stress due to lateral thrusts. I plead not guilty and would refer him to page 10 wherein 10—20 per cent is all that is mentioned.

I thank Mr. Bose for kindly pointing out the slip in line 19 of page 19. The correct word is "maximum" and this maximum is about 60′.

Regarding the information required by him as to the feasibility and advisibility of welding rails of a light section, I must say that I have no information on the subject, if, as I like it, he refers to tram rails when he mentions rails of a light section.

Coming next to the discrepancy pointed out by Mr. Bose re: rail stresses, I must explain that the alleged discrepancy is only apparent, but not real.

Normally rails are capable of being stressed upto a limit of 14 tons per sq. inch, but they are usually very much under-stressed, because of the weakness in the fish-plated joints. Welded rails, although internally stressed, due to welding and temperature stresses, to an extent of upto 5 tons per sq. inch, have still a longer range of effective strength of upto 9 tons per sq. inch, and hence are capable of carrying heavier loads.

Most of Mr. Roy's comments appear to have been made on the mistaken impression that I recommend for adoption on Indian Railways all the modern tendencies in track design, but such is not the case. I have in many instances given my recommendations for adoption on Indian Railways at the end of the various design aspects and would request Mr. Roy to go through them in reply to many of his comments.

In particular my recommendations for use of welding of rail joints are confined to the instances mentioned in page 32 of my paper.

He appears also to have misinterpreted to mean that the 100 per cent saving annually on capital cost of the extra expenditure on welded joints, can be obtained in every case and in

every country. No. 100 per cent saving can be obtained only in Western countries where manual labour is much costly as compared to India, and only in those circumstances where the cost of a welded joint is only 50 per cent extra as compared to the cost of a fish-plated joint.

Mr. Roy may know that the standards of rails for Indian Railways are :

Broad Gauge, 75, 90, 115 lbs. to the yard.

Meetr Gauge, 60, 75 lbs. to the yard.

He appears to have a mistaken impression that relaying of rails are seldom necessiated by rail wear or hogged rail joints. While his impression may be correct as far as Indian Railways are concerned, he is erroneously wrong in the case of the railways in the Western countries. Even in India such a contingency is bound to arise in the course of the next 15 or 20 years.

Mr. Roy mentions of the cost of cutting welded rails, by Oxy-acetylene process at a time when they require changing, but forgets the cost of keeping fish-plates greased or graphited during the life of the rails.

It is not known why Mr. Roy doubts that with welded rails creep will be less. The reason is obvious. The actual forward movement of rail is made possible by the extra gap provided in the holes in the rail for the fish bolts, and when there is no such provision existent in the case of welded rails, there can be no creep either.

Mr. Roy is evidently enamoured of hard wood sleepers because they are used most on E. B. Rly. I am however to draw his attention to the reports of the Track Standards Committee wherein he will find it clearly stated that the only consideration governing the policy of selection of sleepers, in normal circumstances, is the annual cost of the sleeper itself.

The *Cuts* used on the N. W. Rly. are obtained from unserviceable scrap. Sleepers as such cost very little. Ten sleepers are quite sufficient to keep the gauge even on main lines, but are insufficient to keep the alignment, but on branch lines, where speeds are less than 25 M.P.H. or where electric stock are used, 10 sleepers are ample to keep both gauge and alignment.

Lastly, I must correct Mr. Roy's scepticism in the advantages to be had from the use of a greater number of dog spikes. Even in India on many railways two dog spikes per sleeper are considered inadequate for the requirements of branch lines. The advantages of a larger number of dog spikes are better gauge, better alignment and less creep. In Bengal however a larger number of dog spikes is detrimental to the life of the sleeper.

At the outset I must thank Mr. Burford for his long and lengthy comments which clearly indicate the patience with which he must have read my paper.

Mr. Burford has opened with an attack on my statement that in combating the lost monopoly Railway administrations have increased the speeds and loads of trains all the world over. This is an undisputed fact. Mr. Burford quotes figures relating to 1932-33 and compares them with 1938 and states that in India at least there has been no increase in the speeds and loads of trains. Let me however remind him that my paper was prepared in the early part of the year 1937 and the figures given therein related to the year 1935 and if these be compared with those of 1925, the increase will be self evident.

Moreover, the discussion as to whether such increase was necessary or not is entirely beyond the purview of the paper. There also appears a tendency in Mr. Burford's remarks to read the whole paper as being applicable to India only, which however is not the intention. The paper should be made applicable to all the railways in the world and considered as such.

While it is admitted that a good drainage makes a better road, I still maintain that the order followed in this paper is the best, as the most improvements in design have occurred in rails, sleepers and their fastenings and not in the design of the sub-grade.

Regarding statistics for the money spent on rail breakages, Mr. Burford's attention must be drawn to the fact that no railway administration can afford more than a few breakages to occur owing to weak rails. No Chief Engineer, who is worth

his name, would take any risk by permitting to allow weak rails in the track. During the years 1920-30, when the speeds and loads of trains made tremendous progress, the breakages on American Railways were many. If we in India have not had a similar experience, it is merely because our Chief Engineers profited by the American experience and relayed all their main lines with heavier sections, before permitting increased speeds and loads.

Resistance welding at workshops is by far cheaper to thermit welding at site and where facilities exist for resistance welding, the resulting economy of adopting resistance welding is unquestionable.

While I admit that several of the appendices suggested by Mr. Burford would increase the value of the paper, it may be noted that even, as it is, the present paper was considered too lengthy by the Institution authorities at the time of acceptance.

I admit that when rails are intended to be welded, reverse camber is not necessary to be introduced in their manufacture.

Mr. Burford has taken the examples given at the end rather literally. They have been quoted to illustrate the principles involved in computing the financial aspects of track design and not as representing actual figures for discussion.

Water-proofing the sub-grade will not suit Black Cotton soil and for such a soil perhaps ashes or sand were the best materials.

I have also admitted in my paper that as far as India is concerned, mechanical appliances are not usually financially justifiable, but appliances for adzing, boring wooden sleepers in renewals can be justified while taking accuracy also into consideration.

Mr. Burford has questioned my taking the same rate of interest for interest purposes as well as for amortization. Let me assure him that I am correct as approved by the financial *pundits* of Railway Board. If he wishes to verify it, he may do so by reference to similar examples worked out in the recently published State Railway General Code.

Regarding Mr. Nariman's comments, most of them did not relate to the subject matter of this paper and hence I do not

venture to answer them here. The only comment really concerning this paper is his desire to know the effects long length of welded rails had on creep. Long lengths of welded rails produced lesser creep, all other conditions remaining the same, as compared to ordinarily unwelded track.

DISCUSSION ON
DEHRA DUN WATER SUPPLY—BANDAL NADI EXTENSION.

(*This Paper was published in Journal Vol. xix, Part II, February 1940, pp. 103-120.*)

In introducing the paper the Author **(Mr. H. G. Trivedi)** said that his object in presenting the descriptive paper on Dehra Dun Water Supply was twofold. One was to provide encouragement to the younger generation to give up their diffidence and not to hesitate in making available to their professional brethern their experience, of even ordinary works they were engaged on. He was sure that the experience of every engineer was that every work, however small, always presented some special difficulties which exercised the ingenuity of the Engineer and which had to be overcome not through a study of books, but through using one's own commonsense. Also, it could not fall to the lot of everyone to carry out research work or to do something original, and so it was no use waiting for something extraordinary to turn up, for one to write a paper on. It was therefore extremely desirable that Engineers should record the experience gained by them in their every day work, noting the special difficulties encountered, and how they had been overcome, as some of these were sure to be of great value to the profession. If therefore the discussion of the paper was able to encourage even slightly the younger members to utilise their spare time in collecting their experience of whatever work they might be doing in the form of papers, his main object in writing the paper would have been achieved.

His second object was to emphasise the importance of a pure water supply, which was a very important factor in the development of a town. As an example he cited the case of Dehra Dun, the water supply of which was so precarious that even the supply from the Baldi springs, which was very hard

and so not much liked by the people, was considered a boon and supplied the needs of the town for as long as nearly 12 years, till Bandal supply, which formed the subject of the paper, was inaugurated. The town had already started growing since Baldi supply was made available and would now grow even more rapidly.

It was a well known fact that the water supply to the villages and a large number of the towns in India was of the most primitive kind and was mainly responsible for the spread of epidemics, which took such a heavy toll of life year after year. He hoped that it would also not be contended that the advantages of a pure water supply were generally not understood by the people. The reasons for this apathy of the public towards this essential necessity of life were not far to seek. The great poverty of the masses and the ignorance of the people stood in the way of any rapid progress being made in this direction. Still the Public Health Engineering Department of the Government of the United Provinces was doing its best to provide piped water supply to as many towns as possible. This would be evident from the fact that in 1920 there were only 12 water works, providing pure water to nearly 12 lakhs people, whereas in 1940 there were as many as 25 water works catering for the needs of over sixteen lakhs souls. Continuing Mr. Trivedi said that it had not been possible to touch the rural population and he suggested that if the Government as well as the communities concentrated their efforts on even one problem, *viz.* that of pure water supply and sanitary surroundings, it would go a long way in raising the standard of health of the masses, living in the villages, who might be considered as the backbone of India.

Mr. F. J. Campos wondered whether papers of a merely descriptive nature, such as the one under discussion, served any special purpose. It would have been much more useful and interesting to the engineering profession if the author had devoted his paper to a closer discussion of certain important aspects of the filtration plant or any other part of the scheme. For instance the process of coagulation, sedimentation and sludge removal was one of the most imporatnt questions connected with rapid gravity filtration. The ideal process was yet to be evolved.

It would be interesting to know that the hopper-bottom "aggregation" tank adopted at Dehra Dun was really developed in connection with the augmentation of the filtration plant at the water works at Asafnagar in Hyderabad (Deccan). When rapid gravity filters were first introduced in India, the method employed in respect of coagulation, sedimentation and sludge removal was to lead the alum-treated water through a shallow, baffled mixing channel into one or two large rectangular tanks having central longitudinal drains at the bottom, with the floors sloping towards the drains. These drains were covered but had openings into them at regular intervals. They terminated in sludge valves outside the tanks. This was the arrangement adopted in the case of the original plant at Asafnagar, which was at the time the largest of its kind in the East. It was expected that if the sludge valves were opened, the superincumbent load of water would drive the whole of the deposited sludge out. Actually, however, nothing of the kind happened. Only the sludge immediately in front of the valves was driven out. The rest went on accumulating until it had to be removed by manual labour. Apart from the cost of such labour, the accumulation of the sludge curtailed the retention capacity of the tanks and was also prejudicial to efficient filtration as the sludge tended to become septic.

There were two main reasons for the failure of such thanks. One was the insufficiency of the slopes of the floors towards the drains : it was now known that sludge would not move along slopes which were less than about 60°. The other was that the openings into the drains were too large compared with the carrying capacity of the drains ; the result was that only the first few openings nearest the sludge valves functioned, the rest not at all.

Various improvements of this type of tank had been effected, such as the introduction of serrated floors, under-drain system of perforated pipes, etc. These had, however, not proved quite successful. A fairly equal draw-off over the entire drainage system was possible. But the difficulty about moving the sludge along the slopes still remained, because the provision of 60° slopes in such tanks was a costly proposition. There was also another difficulty. If once some sludge had deposited itself around or between the openings into the drainage system, it had the tendency to rapidly build itself up and thus to vitiate the slopes provided.

The logical solution of these difficulties would, therefore, seem to be a hopper-bottom tank with some arrangement that would keep the sludge constantly in motion until it was finally removed. Such a solution was adopted for the first time in the case of the augmentation of the plant at Asafnagar. It was proposed to pass the alum-treated water first through hopper-bottom primary tanks and then through secondary tanks, more or less as described in the paper under discussion, but with the exception that the deflector boxes in the primary tanks were not to extend to the bottom of the tanks but were to be only a few feet deep. The primary tank was an adaptation of the Dortmund tank long in use in sewage disposal works and its object at the time when it was first proposed was merely efficient sedimentation and sludge removal under hydrostatic pressure. When the plant was in course of construction, however, "mechanical flocculators," or what might be briefly described as rotating paddles, started coming into prominence, particularly in America. These flocculators worked on the principle that if "floc", which was in the incipient stage, was brought into intimate contact with the floc which was already formed, coagulation was much more rapid and efficient. This was the genesis of the idea that the primary tank at Asafnagar might, with some modification, be adapted to the purpose of "aggregation" of the floc. Experiments showed that this could easily be done by merely extending the deflector box to within a few feet of the bottom of the tank and providing it with a tapered outlet. The necessary modification was made and the primary hopper-bottom tanks at Asafnagar served as "aggregation tanks". What actually happened was that the alum-treated water was diverted through the deflector boxes to the bottom of the tanks where it came into intimate contact with the deposited floc. This led to efficient "aggregation". The water then rose with decreasing velocity and in consequence the heavier impurities were precipitated and only the finer particles were picked up into the decanting channels and thence passed on into the secondary tanks. Sludge-removal in both tanks was done by means of a pipe at the bottom discharging the sludge under hydrostatic pressure into adjacent sludge channels. This was the type of tank since installed at Dehra Dun.

This solution was a great step forward, but it should not be thought that it had no drawbacks. One great drawback was the expense involved in the hopper-bottoms and the mehcanical

fittings. Also the aggregation tank required close attention and had to be desludged in time, otherwise a cloud of sludge rose up in the tank and passed into the secondary tank. It was also being experienced that different turbidities required different spacings between the outlet of the deflector box and the bottom of the tank. This difficulty could of course be obviated by the provision of an adjustable outlet, which could be made to work automatically; but this meant additional expense. The secondary tank had not been quite a success. The bottom of this tank was provided with adequate slopes towards the mouth of the sludge-removal pipe along two sides of the tank, but with only a gentle slope along the other two sides. The consequence was that all the sludge was not removed through the sludge-removal pipe and the sludge went on accumulating as in the case of the ordinary rectangular tank. Results seemed to indicate the advisability of eliminating the secondary tank altogether and concentrating the three functions of aggregation, sedimentation and sludge-removal in one and the same hopper-bottom tank. This, however, would require careful experimentation.

Mr. Campos said that he had gone into the above question at some length solely with the object of indicating the difficulties of some of the questions connected with filtration of water. These difficulties could not be solved unless each one of them was individually tackled and unless the results of the experiments and observations of Water-works Engineers were pooled together and discussed on a common platform such as that of the Institution of Engineers (India).

Mr. E. A. Nadirshah in opening the discussion at a meeting of the Bombay Centre said that the paper was incomplete in the absence of sufficient data, descriptions and results, and that as such was not useful to those who wished to make use of it at a later date for solution of their problems. He found that no complete plans were submitted. He was of opinion that a mere statement that such a source of water was rejected on account of hardness of water was not very helpful. It would have been much better if the Author had thrown some light on the type of hardness and the attempts made to soften it. He was also surprised to note how the authorities spent large sums on digging wells when there was no provision for a pump.

Mr. Nadirshah then very clearly explained to the members the salient features of the paper by use of the plans which the representatives of the Candy Filters Co., had very kindly made available to him.

It was the general opinion of members present at the meeting that in the discussion of this paper at other Centres more detailed plans of the scheme should be called for from the Author.

Diwan Bahadur V. G. Shete congratulated the author and commented on the use of different kinds of rapid fillers in use in India. He remarked that the reasons for preferring Candy Filters were not stated nor was the total loss from inlet of raw water to outlet end for pure water tank given. The guarantees for the quality of water to be obtained after filtration should be definitely stated.

About the gravitations pipe line he gave the instance of a pipe line in the Deccan, about the same length as that of the Bandal Scheme and stated that after a period of 40 years or so the discharging capacity of the main had been much reduced due to silting and ageing etc. In this case the head under which the pipe line was expected to work was 155 ft. in a length of 42467 ft. and was stated to give a theoretical discharge of 520 gallons per minute equal to about 7½ lacs of gallons per head per day. It was very essential to know what formula was used and at what age of the pipe line the theoretical discharge was calculated.

The experience of steel piping used in Bombay Presidency at some three places was found to be very bad, the pipes having got pitted and holed though these were at first specified to be coated and wrapped with Hessian cloth. At all these places the pipes had to be renewed after a period varying from 10 to 15 years and therefore on consideration of their life, their ultimate cost did not prove to be economical. He hoped that the authorities concerned had considered these points very carefully before coming to the conclusion to the adoption of these pipes finally.

About the available supply being only 16 gallons per head, the author seemed to rely much on the use of meters for economies in consumption. This might not be exactly what would

happen in practice and statistical figures about consumption for year to year, month to month, in different seasons would have to be carefully recorded and watched to enable future provisions being arranged well in advance before the work had reached their designed capacities.

Descriptions of works carried out in recent years were very helpful in comparisons and the attempt of the author in presenting the paper to the Institution would prove a best guide to those who fought shy of writing them.

In replying to the comments the **Author** said that he did not agree with Mr. Campos when he said that merely descriptive papers served no special purpose. The object which the author had in presenting the paper was clearly stated in his opening remarks.

The description of any work was useful and the object of his paper was to place on record the work as a whole connected with the provision of the Bandal Nadi Extension and not to deal with any particular point in detail. If he had dealt with the process of purification in as much detail as Mr. Campos had done in his remarks, he would have had to mention such other matters as the method of washing the filters, which was of equal importance and interest from an engineering point of view. In that case the space occupied would have been colossal.

He did agree, however, with Mr. Campos that remarks such as his were extremely useful for the purpose of pooling information.

Referring to Mr. Nadirshah's remarks the author said that full detailed plans were submitted by him along with the paper, but that in order to minimise the cost of printing he was asked to reduce the number, and so he attached only the most important plans to the paper.

He had made only a mention in his paper that the experiments in softening the Baldi water proved that the softening process was by no means an easy one and the cost would be prohibitive for the full supply required for Dehra Dun. The

fact was that the Baldi water, which used to supply the needs of the major portion of the town, varied in hardness from 20 to 90 total hardness, the proportion of temporary to permanent hardness being roughly 1 to 2.

In March 1929 Messrs. The Paterson Engineering Co. (India) Ltd. were given a contract for a softening plant capable of treating 220,000 gallons per day and the price tendered was Rs. 28,550/-. The firm took their own samples to satisfy themselves and guaranteed the amount of chemicals required to reduce the hardness of water by 1° permanent and 1° temporary for 10,000 gallons as follows :—

Soda Ash	1 lb.
Lime	0·56 „

When, however, the plant was tested, the results were very unsatisfactory and it was found that more than double the guaranteed quantity of chemicals would be required to soften the water. The plant was, therefore, rejected and it became necessary to find a source, the water from which would not require the installation of a softening plant.

Mr. Nadirshah had also expressed surprise how the authorities spent large sums in digging wells when there was no provision for a pump. In this connection the author said that the experiment for boring was mainly carried out to get an artesian supply. This was not obtainable. The sub-soil water level was more than 300 feet below ground level, hence even if a sufficient quantity of water were available, the pumping of the full supply, required for Dehra Dun, would have been very costly. Moreover, the water-bearing strata encountered did not give any hope of obtaining a reasonable supply of water. Consequently any further expenditure on testing it was considered as waste of money.

The author then dealt with the points raised by Dewan Bahadur Shete and supplied the following further information wanted by him :—

Tenders for the filtration plant were received from Messrs. The Paterson Engineering Co., (India) Ltd., Calcutta, Jewell Filter Co., Ltd., Calcutta and Candy Filters (India) Ltd., Bombay.

Candy's plant was preferred because the design of the filters, which they offered, was in accordance with the latest ideas and practice, whereby an undoubted saving of wash water was expected. Their control apparatus and their chemical proportioning administering gear were also in accordance with the most recent practice. They did not employ the high pressure air agitation system and the direct low pressure system they offered tended towards economy. The guarantees that they gave were also satisfactory and specially their guarantees of the amount of water, required for filter washing, was 50% below that of the Paterson Engineering Co.

When the plant was tested after completion, it was found that the wash water consumption was only 0·35% for the period 27-5-37 to 7-7-37.

The guarantees given by the firm were as noted below :—

"1. That the effluent will be a clear sparkling water free from taste and odour when heated to 37° C, free from residue of coagulants and such that a platinum wire 1 m.m. in diameter will be visible at a depth of 6 ft. to a person of normal vision in clear midday light.

2. That the filtered water will not normally contain more than 50 total colonies per c.c. after 24 hours' incubation on appropriate media.

3. That the treated water will not have an acid reaction under any circumstances and will contain alkalinity to the extent of not less than 1 part per 100,000 calculated as $CaCo_3$.

4. That the albuminoid ammonia content should not exceed 0·1 parts per million.

5. That B. Coli and lactoes fermenters shall not normally be present in 100 c.c. of the sterilized water after the requisite contact period.

6. That the purification plant shall effect removal of 100% of the suspended matter from the raw water as estimated by the usual laboratory weighing methods.

7. That the purified water shall be fit for all dietetic and household purposes and that there shall be no deterioration in the taste of the water.

8. That the purified water shall conform to the standards laid down by the Director of Public Health, United Provinces.

9. That the wash-water consumption will not exceed 1% of the total water filtered on the average and in practice it should not exceed 0·5%.

10. That the quantity of sulphate of alumina required shall not exceed 3 grains per gallon and the quantities of chlorine and ammonia shall not exceed 0·5 and 0·2 p.p.m. respectively on the average."

The above guarantees were amply fulfilled.

The water level in the flume channel, as it was discharged from the gravity mains, was R.L. 2306·00 and the top water level in the clear water reservoir was R.L. 2294·50. Thus the total loss of head was 11·5 feet only.

With the head available, the maximum discharge expected from the gravity main was 1½ cusecs according to Boxes Hydraulic Tables.

As the country was a difficult one, being hilly, steel pipes were the only pipes that could be conveniently used for the gravity main. Steel pipes laid under similar conditions for Baldi supply had been giving satisfactory service for the last ten years and it was not doubted that any trouble would be experienced from steel pipes in this line also. Recently however, it has been noticed that flakes of paint were coming off from the inside of the pipe line and collecting in the module near the headworks. A few of these flakes had found their way into the settling tanks also at the filtration plant. A keen watch was being kept and the advice of Messrs. Stewarts and Lloyds had also been asked for.

The application of meters in each and every case had been found extremely useful in keeping down the consumption, and although the metered connections had more than doubled since this paper was written, the total supply had not much increased.

DISCUSSION ON ENGINEERING IN THE INDIAN PAPER INDUSTRY.

(This paper was published in Journal Vol. XIX, Part II, pp. 121-146)

Mr. F. E. Bharucha in opening the discussion said that there were 11 paper factories in India with a production of 60,000 tons per year. As the Government of India did not give any protection to this industry, paper industry in India had to face a keen competition from abroad. India had sufficient raw materials except some chemicals for the manufacture of paper. Present import figures of wood pulp was about 13,800 tons valued at Rs. 26 lakhs. Pulp came from Norway and United States of America. Germany exported mainly Scandinavian pulp. Research work at Dehra Dun was very slow and no conclusions had been arrived at as regards use of Bamboo for high class paper. Moreover the benefit of research went mainly to foreign countries as very little publicity was given to the results of such researches amongst Indian industrialists. The greatest demand in India was for newsprints but unfortunately it was not manufactured in India. Packing paper mainly came from Germany, Sweden and Norway.

Mr. Bharucha complemented the Author for his very valuable paper and expressed a hope that papers on Technology like paper, sugar, etc., would be forthcoming. He noted that Mr. Beattie had avoided giving figures regarding the cost of manufacture. Mr. Bharucha then explained for the convenience of the members, salient features of the paper, page by page, and also explained the 8 stages of manufacture of paper. He explained how the steam power was most economical in paper industry because of the facilities of using exhaust steam for process work.

Mr. R. K. Nariman remarked that although paper was now manufactured in Scandinavia, Newfoundland, etc., in large quantities, it originated in China and Egypt. He thought that

Mr. Bharucha was not right in criticizing the Government for not giving protection to the industry as due to Government encouragement some old established paper Mills were doing well.

Mr. Burjor S. J. Aga enquired as to the cause of paper losing its tenacity and becoming brittle. He also wanted to know whether the pulp made from Pine wood was good.

Mr. F. E. Bharucha in reply said that the quality of paper was damaged by the use of chemicals. As regards Pine wood, he said that research work was necessary.

Mr. D. N. Jayakar explained how India was one of the leading exporters of paper in the days of the East India Co.

Mr. J. D. Daruvala complemented the Author for his valuable paper and thanked Mr. Bharucha for having explained it to the members in such a lucid way. He was of opinion that Government had sufficient powers to prevent profit making and that it could not be given as an excuse for not giving protection to the industry.

DISCUSSION ON
TENTATIVE HYPOTHESIS ON THE NATURE OF FRICTION WITH ITS BEARING ON ENGINEERING QUESTIONS INCLUDING FLOW OF WATER

BY

S. B. JOSHI AND R. N. JOSHI

(This Paper was published in Journal Vol. XIX, Part, II, February 1940, pp. 147-158.)

Mr. N. B. Gadre read the Paper with great interest and was much impressed with the force of arguments given in the Paper. He had no doubt that the explanation of the nature of Friction was on right lines, and he congratulated the Authors for the originality of their views.

Prof. M. R. Paranjape wrote that the explanation of the apparent contradiction between the Friction between Solids and Fluids and that between Solids and Solids appeared to him convincing.

Mr. G. N. Gokhale was delighted to read the Paper on Friction. In fact he had always taught in his classes that in Rolling Friction there was no relative motion between the surfaces in contact. He thought that the Rolling Friction was really the energy spent in lifting the weight over every little projection.

He congratulated the Authors very heartily and hoped that they would get the recognition they deserved.

Mr. R. S. Deshpande congratulated the Authors upon their Paper on the 'Tentative hypothesis on the nature of Friction'. He thought that the theory advanced by the Authors explained all the aspects of frictional resistance. It threw an altogether new light on the laws governing the flow of water and he thought that the theory could be developed to explain all the laws of hydraulics. Several points in hydraulics which were blindly accepted so far had become intelligible.

He thanked the Authors for their original and far reaching theory.

Mr. E. R. Wiseman (*Department of Mechanics, Rensselaer Polytechnic Institute, Troy, N. Y.*) *wrote:* "I have looked over the Paper on Friction and find it the best rational treatment of the subject I have ever come across.

I believe it would be clearer for one not accustomed to the terms, if the term B, Wetted Perimeter, is described a little more in detail."

Mr. F. Jonassen (*University of California, California.*) *wrote:* "Graphical presentations of the critical and ultra-critical velocities do not appear to be tenable with the commonly accepted theory of modern fluid mechanics in which it is assumed that a very thin layer of fluid in laminar motion exists near the solid boundary. This laminar layer exists even when the flow is turbulent, *i.e.* ultra-critical.

In the derivation of the equation describing the flow of water the Authors find that the slope of the energy gradient is a function of a "constant" plus a second "constant" times the first power of the velocity plus a third "constant" times the second power of the velocity. While this relationship is undoubtly true, *i.e.* the energy slope is conditioned by viscous resistance and turbulent resistance, no method has yet been found whereby these constants can be evaluated to make them of universal application.

If the flow is assumed highly turbulent, then it has been found that the slope of the energy gradient is directly proportional to the square of the velocity whence the Constants C_1 and C_2 have become very small and may be neglected. When this is the case, the C in the Chezy equation (C_3 in the Paper) has been found to be a function of the conduit surface only, but in no instance is it constant except in the same conduit and in other conduits of identical roughness.

On the other hand, if the flow is not highly turbulent, *i.e.* shallow depths and low velocities, then viscous effects will manifest themselves and the equation, as the Authors have derived it becomes useful since it is of the correct form. Under

this condition the C in the Chezy equation is a function of the surface roughness and the viscosity of the fluid.

At present it does not appear possible to postulate that these constants (C_2& C_3) can be evaluated to make them universal in application."

Mr. Gleason H. MacCullough (*Professor of Engineering Mechanics, Department of Mechanical Engineering, Worcester Polytechnic Institute, Massachusetts*) wrote that he read the paper with much interest and believed that the propositions were soundly stated.

Dr. S. R. Sen Gupta : Theoretical objections to Messrs. Joshi's Hypothesis on Friction are far too numerous to be acceptable *even* to the engineers. As this note is to be in the nature of remarks and not a paper on the subject I shall restrict myself to pointing out *only a few* of the objections. I shall deal with the exposition of the hypothesis as applied to sliding friction, rolling friction and to fluid friction.

Sliding Friction : Let us imagine, with Messrs. Joshi, that the surface of an apparently smooth object consists of corrugation, however minute these may be. (At once, a questionable hypothesis). Let a particle travelling at constant velocity along such a surface (Fig. 1 of the paper) be moving up the positive slope of one of these corrugations, the force required is then positive. When this particle descends along the other side of the mound the force required is obviously negative. It is difficult to see why the average force is going to be positive, unless we assume that these mounds have different slopes on the two sides. Granting *even this* to be possible, what happens when the particle is travelling in the opposite direction. What will be the average force required? Will it be the same? It can be the same only if the surface at once alters its nature to suit Messrs. Joshi's Hypothesis. An explanation is naturally called for.

Rolling Friction : The part dealing with rolling friction is incomprehensible. What do the Authors mean by "Least Integral Resistance"? I would request the Authors to consider the motion of a spinning sphere on a plane in the light of their hypothesis. I cannot see how we can accept their hypothesis without further clarification.

Fluid Friction and Chezy Formula : The initial portions of this section is open to the same objections as before.

The deduction of the velocity formula is *far from* clear, if not wrong.

How do the Authors obtain the volume of the fluid sheared? A detailed derivation is most certainly required.

The formula applied in deducing the expression for the shear strain energy is applicable only (i) when the shear stress is below the elastic limit and (ii) when the elastic body is in a state of uniform shear. On what grounds do the Authors apply this formula to fluid in the boundary?

Is the velocity V uniform in this layer? If so there cannot be any question of shearing stress.

What is the thickness of this layer?

The writers then invoke the aid of viscous flow in deducing the expression for the energy loss in the rest of the fluid. The formula deduced is dimensionally wrong unless K has dimensions. Assuming, K is dimensional, it presupposes laminar flow, which is certainly not the case in a channel. Further if the velocity V is assumed uniform then the flow is that of perfect fluid and as such the fluid is devoid of friction.

The justification for the Author's formula on velocity seems to rest only on the derivation of the Chezy Formula as a corollary, and as such we cannot possibly accept this hypothesis unless this derivation is given in a more detailed manner, so as to be comprehensible, and meeting all the objections.

Concluding Remarks : Messrs. Joshi made the sweeping statement that Chezy Formula has no rational basis.

A much more rational deduction than that supplied by the Authors follows from Dimensional Analysis (as follows):

By the Method of Dimensions, the resistance F is given by

$$F = \rho v^2 d^2 \varphi \left(\frac{\mu}{\rho v d}, \frac{g d}{v^2}, \frac{v_S}{v}, \frac{c}{d} \right)$$

for a fluid, where

v = Representative Velocity

d = Representative length

μ = Co-efft. of viscosity.

ρ = Density.

g = acceleration due to gravity.

v_S = Velocity of sound in the fluid.

$\frac{c}{d}$ = Roughness factor.

for liquids flowing in reasonably smooth tubes or channels a good approximation to F is given by

$$F = \rho v^2 d^2 f \left(\frac{\mu}{\rho v d} \right)$$

For dynamically similar flow $f \left(\frac{\mu}{\rho v d} \right)$ Constant C

Hence, Friction loss F for dynamically similar flow

$F = C \rho v^2 d^2$

The Chezy formula at once follows (see Gibson's Hydraulic for derivation).

It is not my intention to discourage Messrs. Joshi or to discount their attempt but we certainly cannot accept their hypothesis as exposed in their paper until and unless we obtain a more detailed explanation preferably in a mathematical form and meeting some of the objections the hypothesis is open to. The Authors should also give a comparison of their theoretical result with the standard experimental results.

Mr. P. C. Mitter *wrote* : The first laws of Friction enuciated by Coulomb in 1781 and afterwards confirmed by A. J. Morin 1830-1834 are good enough within wide limits. These are :—

(*1*) *Friction is proportional to the normal pressure between two surfaces of contact, and are independent of area.*

(2) *Friction is independent of velocity, except between certain limits.*

It was well-known, long ago, that, Friction is Resistance only—not a force in itself. The result of an outside force, applied to materials or substances in contact, appears to our senses as movement, under obstruction which wholly depends on the nature of the materials or substances in contact.

When a solid slides on another solid, the same reactions are present, as when liquid (or gas) slides on a solid. The only difference is that, in the first instance, the solids retain their shape approximately, whereas in the second, the liquid does not keep its shape and its particles re-arrange among themselves producing a new shape or shapes resulting under the circumstances (which are dependent on the nature of the solid and liquid in contact and the force itself).

When the shape of the channel in which the liquid moves is nearly regular, (practically constant as in a river), the section of the moving liquid also apparently appears as constant, although great changes in the internal arrangement of its particles have taken place.

In most of the best observations on Rivers, it has been found that the greatest velocity in a flowing stream is not at the surface, but at some distance below it. The velocity at bottom and sides, in contact with the wetted perimeter, is the smallest.

With the blowing wind down-stream, the surface velocity increases ; up-stream, the surface velocity decreases ; but in all cases the greatest velocity is below the surface.

This retarding action of the water at the surface is not due to wind, for, then the surface velocity would be greatest with wind downstream which is not the case.

This shows conclusively that there is re-arrangement of particles or of planes of moving liquid, although apparently no relative motion may be noticeable except without scrutiny.

The shearing action of the surface of wetted perimeter, affecting the moving liquid, is confined to a portion of the depth only. This is confirmed by Froude's experiment and observation.

The relative velocity of particles, in a vertical plane, in a moving stream of liquid approaches the form of parabola, the vertex being at a depth below the surface.

This has been found out by American writers and curves for calm weather and up-stream and down-stream wind have been drawn by them.

Clearly, the velocity at bottom is retarded resulting from Friction. Then, there is tendency to (and there is actual) rupture between horizontal plane sliding on horizontal plane (also between strips, and also those at sides, sliding on those, at the centre). Thus a great amount of energy is lost internally which depends on the particular constitution of the liquid in each case and also on actual condition governing same.

Then, as a particle slides past another, vacuum is formed, to fill up which particles from upper layer rush in, and collision bombardment, which result is another source of loss of energy.

The above losses are not fully taken into account by Messrs. Joshi's expression for work done.

Conclusion :—(1) Thus it can be seen that Messrs. Joshi's equation on page 157 is by no means exhaustive and complete.

(2) Existing formula, Chezy's formula and others are all in the form $V = C\sqrt{rs}$ which are convenient and which serve their purpose fairly well Messrs. Joshi's is in from $V = C\sqrt{r} + C_1 r$ and is more complicated although mathematically this appears somewhat more exhaustive.

(3) In all these formulae, C, C_1 C_2 play a great part which must be determined quantitatively and which are by no means eliminated or simplified by Messrs. Joshi's formula and which must be determined by experiment in each case.

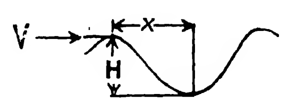
It is to be seen that all such formulae must further be modified according to the nature of chemical action involved between the surfaces in contact as well as adhesion (taken partly into account by Messrs. Joshi) which should involve another constant to make it more complete.

Practically however all these formulae will be more or less empirical. It will depend on Engineers to chose what formula they use."

Mr. S. R. Shroff *wrote:* On page 154 of the paper an explanation of critical velocity has been given. It is suggested that when water flows over a rough surface its particles after dashing against the sides of the troughs of the rough surface are reflected as shown in fig. 5 of the paper. Further it is suggested that at critical and sub-critical velocities the particles are not reflected backwards but at ultra-critical velocities they are so reflected.

I, however, suggested that all the above three types of reflections shown in fig. 5 of the paper take place no matter what the velocity of water happens to be. The reason is that the type of reflection that a particle of water undergoes is not dependent upon its velocity alone. It also depends upon the shape of the trough. Thus if V is the velocity of water, T the time taken by a particle of water to fall through H the height of the trough and X that part of the width which is situated between the highest and lowest point as shown in the fig. below then the condition that a particle of water shall not be reflected backwards is given by the equation :—

$$VT = X$$



In an actual piece of material the troughs will be of many different shapes hence all kinds of reflections will take place at all velocities.

The reason why no turbulance is set up at critical and sub-critical velocities is that at these velocities the particles of water do not possess sufficient kinetic energy to overcome the viscous resistance of the fluid and set up turbulance.

It will also be seen that the explanation given in the paper leads to the erroneous conclusion that the critical velocity of a fluid is independent of its nature because the troughs are independent of the nature of the fluid. On the other hand my explanation leads to the correct conclusion that the more viscous and the less dense a fluid is the higher its critical velocity as in the former case the resistance to turbulance is greater and in the later case the kinetic energy of the particles is less.

The Authors (*in reply*): Dr. Sen Gupta questions the validity of our statement that the smoothest surfaces we get in practice are more or less rough and irregular. He should know that an hypothesis is never meant to convey a physical actuality. It is a set of assumptions on the basis of which all experimental observations can be inferred. We have made the point clear in our Paper on page 148, where we have said "we do not propose to hypothesize on the constitution of matter as such. Ours is a mechanical hypothesis giving rational explanation of the Phenomena of friction and putting most of the well-known results of Friction in a logical sequence." Further we may inform Dr. Sen Gupta that irregularity of smooth surfaces has been the assumption of most of the theories presented on the nature of friction till this day.

Dr. Sen Gupta finds a great difficulty in finding why the average force is always positive. He thinks that a force on the upward slope of a mound is positive and that on the downward slope is negative. In order to an give average positive resultant force he finds it necessary to attribute to the theory that every mound has different slopes in the opposite directions, the slopes in the direction of motion always being flatter than those in other direction. To reduce the theory to an absurdity, he goes a step further and infers that probably these slopes at once alter their positions when the direction of motion is reversed in order to suit 'Messrs. Joshi's Hypothesis', as Dr. Sen Gupta would like to put it.

We regret Dr. Sen Gupta has not caught the point. First, consider the static condition of the bodies. When an upper body is at a standstill, it rests on the lower body in a state of stable equilibrium, *i.e.*, it rests as far as possible in the troughs of the lower body, so that the centre of gravity of the upper body occupies the lowermost position in that neighbourhood. Now when a force is applied to the upper body in any direction, in order to be able to move forward its centre of gravity is required to be raised, and the force applied is required to do that work. It will therefore be seen that a positive force is always required to move a body from its state of rest in any direction.

During motion the contact points on the downward slope assimilate some kinetic energy, which partly helps the body up the facing inclines and the rest of the energy is lost in heat. This matter has been fully dealt with in the body of the Paper.

There is always resistance to motion, as long as there is some obstacle in the forward path, *i.e.*, as long as there are some contact points on the upward gradients of mounds. Assume for the sake of argument, that during motion, a stage comes, when there is no contact point on the ascents and when all the contact points are on the descents. At such a point there is no instantaneous resistance. The force applied during the fraction of a moment accelerates the body only to be hinde ed the next moment by the facing obstacles.

It may be noted that ordinarily a contact point on a descent seldom continues to remain a contact point in effect after the application of a horizontal force.

It is therefore clear that doubts raised by Dr. Sen Gupta regarding the negative force and the necessity of a sudden metamorphosis in the nature of the surfaces have no significance.

Then Dr. Sen Gupta goes to the portion on Rolling friction, and finds that too beyond his comprehension. His first difficulty in following our explanation on Rolling friction is with regard to least integral resistance. We cannot find any reference to Least Integral Resistance under Rolling friction in our paper. Without understanding the fundamental notion of the "Least Integral Resistance" if Dr. Sen Gupta wishes to know the rest of the theory, probably it is no wonder that it is beyond his comprehension. For the explanation of the term "Least Integral Resistance", we refer him to page 149 of our Paper, Para 5. "Therefore the number of ways in which the N obstacles can be overcome is 3^N, and they are actually overcome by that particular combination for which the integral resistance is the least."

Then again continuing his remarks on Rolling friction Dr. Sen Gupta asks how we can explain the case of a spinning sphere. Here again the condition of the spinning sphere has nothing to do with rolling. Spinning of a sphere is sliding pure and simple, same portions of the surfaces coming in contact over and over again. Everything that applies to sliding bodies, equally applies to the spinning sphere as far as frictional resistance is concerned.

Further dealing with the portion of Fluid friction, Dr. Sen Gupta wants to know how we have obtained the volume of liquid sheared. It can be easily seen that the height of obstacles is $\frac{\delta l \tan \varphi}{2n}$ where φ is the angle of inclination of obstacle and n the number of obstacles in a length of δl. If now the perimeter B is supposed to be spread out, it will form a plane surface of length B and with obstacles of height $\frac{\delta l. \tan \varphi}{2n}$ standing on it. If it is assumed that the volume of the liquid sheared due to the obstruction of the obstacles is two-thirds of the volume made up of length B, width δl and height $\frac{\delta l. \tan \varphi}{2n}$ we have

$$\text{Volume of liquid sheared} = \frac{B.\ \delta l.\ \tan}{2n} \times \frac{2}{3} \times \frac{\delta l}{l}$$

$$= \frac{B.\ \delta l.\ \tan \varphi.\ \delta l}{3n}$$

$$= C\ B\ \delta l.\ \tan \varphi.\ \delta l.$$

It should be noted that the value of the constant C is immaterial and that it does not affect in any way the form of the equation of the velocity of flow.

Dr. Sen Gupta raises objection to our using the expression for shear strain energy when the shear stress is beyond the elastic limit and when the elastic body is not in a state of uniform shear. A perfect fluid does not offer any resistance to shear at all. Liquids met with in practice do offer resistance to shear ; but unlike solids, after getting sheared they recover to their original state (the property known as fugitive elasticity). And in the case of liquids, like water say, there is no difference between the elastic limit and the yield point. There can therefore be no objection to our using the expression of stress strain energy for finding the energy consumed in shearing the liquid.

It needs no explanation to show that internal viscous resistance is caused by relative motion of layers of the liquid. It is obvious that such relative velocity between successive layers of the liquid exists and that the velocity is not uniform throughout. The dimensions of K in the expression of the

loss of energy in the viscous resistance, could be easily arrived at by equating the dimensions of the expression to the dimension of energy.

We have said in the paper that the Chezy formula is empirical, which means that Chezy's formula is based on experimental observations. This does not convey that the Chezy's formula has no rational basis at all. Why should Dr. Sen Gupta allege to use a statement which we have nowhere made in the paper?

Dr. Sen Gupta proceeds to give his rational deduction of Chezy's formula based on dimensional analysis and dynamical similarity. Although this part of Dr. Sen Gupta's comments has no relevance to the subject matter of our paper—it is worthwhile examining Dr. Sen Gupta's rational deduction of Chezy's formula.

Dr. Sen Gupta finds a good approximation to F by neglecting the factors $\frac{gl}{v^2}$, $\frac{v_s}{v}$, $\frac{c}{l}$ for liquids flowing in reasonably smooth tubes or channels. Dr. Sen Gupta forgets to mention the important fact that the factor $\frac{gl}{v^2}$ is neglected because the flow is unaccelerated.

Then Dr. Sen Gupta states that for dynamically similar flow $\varphi\left(\frac{\mu}{\rho vl}\right) =$ constant $=$ C, as if dynamical similarity is an essential attribute of all hydraulic phenomena.

Dr. Sen Gupta should know that there are many hydraulic phenomena which are not dynamically similar. Lines of flow and wave formations around a ship and its model in the same fluid cannot be made dynamically similar. There is some confusion in Dr. Sen Gupta's mind. He appears to have assumed dynamical similarity first and derived his equation $F = c\rho v^2 l^2$ next. If he assumes dynamical similarity first it is not necessary for him to write all these equations. The equation $F = c\rho v^2 l^2$ follows from the very definition of dynamic similarity.

If Dr. Sen Gupta had taken into account both the factors $\frac{\mu}{\rho v l}$ & $\frac{lg}{v^2}$ he would have got the relation $F \propto \rho l^2 v^2 \left(\frac{lg}{v^2}\right)^q \cdot \left(\frac{\mu}{vl\rho}\right)^p.$ Dr. Sen Gupta would then have put $\varphi\left(\frac{\mu}{vl\rho}\right) =$ constant and $F\left(\frac{lg}{v^2}\right)$=constant for dynamical similarity.

This would lead to the impossible conditions $v \propto \frac{1}{l}$ and $v \propto \sqrt{l}$ to be satisfied simultaneously.

It is clear that $\varphi\left(\frac{\mu}{vl\rho}\right)$ cannot become constant simply because Dr. Sen Gupta wants the hydraulic phenomena to satisfy the condition of dynamic similarity.

Let us now see whether the inference $F = c\rho v^2 l^2$ directly follows from $\varphi\left(\frac{\mu}{\rho v l}\right) =$ Constant $=$ C.

The relation $F \propto \rho v^2 l^2 \varphi\left(\frac{\mu}{\rho v l}\right)$ is written from the relation $F \propto \rho v^2 l^2 \left(\frac{\mu}{\rho v l}\right)^p$

Now if $\left(\frac{\mu}{\rho v l}\right)$=constant

For a particular liquid μ and ρ are invariables.

Therefore $vl =$ Constant

Therefore $v^0 l^0$, $v^1 l^1$, $v^2 l^2$, $v^3 l^3$ and so on are all constants.

Therefore all the following relations are equally true.

$F = c_1 \rho v^0 l^0$ or $F = c_2 \rho v^1 l^1$
or $F = c_3 \rho v^2 l^2$ or $F = c_4 \rho v^3 l^3$ and so on.

The fact of the matter is that Dr. Sen Gupta has made a mistake in stating that for dynamical similarity $\varphi\left(\frac{\mu}{\rho v l}\right)$ =Constant = C. He should not have brought in dynamical similarity at all in his derivation. Dynamical similarity not

being an essential attribute of all hydraulic phenomena, it cannot be stated as a reason for declaring any factor like $\left(\frac{\mu}{\rho vl}\right)$ =Constant.

Dr. Sen Gupta should have given his derivation as under

$F \propto \rho v^2 l^2 \left(\frac{\mu}{vl\rho}\right)^{\rho}$.

Because the liquid is more or less incompressible the viscosity has very little effect on the frictional resistance. The value of $\left(\frac{\mu}{vl\rho}\right)^{\rho}$ decreases as ρ decreases so that in the limit as $\rho \rightarrow o$, $\left(\frac{\mu}{vl\rho}\right)^{\rho} \rightarrow 1$ & F can in this limiting case be written as $F \propto \rho v^2 l^2$.

Note :—Nearer ρ approaches zero more does the flow assume conditions of dynamic similarity at all velocities and for all dimensions of tubes or channels.

Mr. Mitter says no theory is complete which does not take into account the constitution of matter. We have given the limitations of our theory in the Paper itself. We do not hypothesize on the constitution of matter. Ours is a mechanical hypothesis.

Mr. Mitter observes that with blowing wind the surface velocity increases but is never greater than the velocity below the surface. Though this has nothing to do with the subject matter of our paper it might be noted that he is not right in making this observation. With strong wind blowing in the direction of the current the maximum velocity is at the surface.

Mr. Shroff has given an explanation of critical velocity on the basis that the reflected particles do not or do possess sufficient energy to overcome the viscous resistance of the fluid and set up turbulence according as their velocity is below or above the critical velocity. Mr. Shroff is right in saying that critical velocity depends on the nature of the liquid. But critical velocity also depends upon the nature of the solid surface.

Thus for a *given liquid* the critical velocity will depend upon the nature of the material in which it is flowing, and for a given solid surface the critical velocity will naturally depend on the nature of the liquid that flows on the surface.

Arising out of the discussion appearing in the forgoing pages, further remarks by Mr. P. C. Mitter, and Mr. S. B. Joshi's replies thereto are appended below.

Mr. P. C. Mitter: Mr. Joshi's statement that "with strong wind blowing in the direction of the current the maximum velocity is at the surface" is neither born out by experiments, nor by the current literature on the subject, and I refer him to P. P. Boileau's Experiments in the Mississipi. If this be accepted, then this shall be found to have something to do with his hypothesis dealing as it has to do with the peculiar constitution of fluids. I am giving below an extract from results of Mississipi Experiments :—

"In the gauging of the Mississipi the vertical velocity curve is found to agree well with a parabola, having a horizontal axis at some distance below the water surface, the ordinate at the axis of the parabola being the maximum velocity of the section".

With a wind blowing downstream, the surface velocity is increased, and the axis of the parabola approaches the surface; with a wind blowing upstream the surface velocity is decreased, and the axis of the parabola is lowered.

In very careful experiments, P. P. Boileau found the maximum velocity, though raised a little above its position in calm weather, still at a considerable distance below the surface, even when the wind was blowing downstream, with a velocity greater than that of the stream."

Mr. S. B. Joshi (in reply): Mr. Mitter will find confirmation of our statement regarding the effect of strong wind blowing in the direction of motion of the current on the position of maximum velocity in any standard Text Book on Hydraulics.

The experiments that Mr. Mitter refers to are for velocities of wind slightly higher than the velocity of the current. But that does not indicate a strong wind. Therefore there is really no contradiction between the statement made by us and the experiments referred to by Mr. Mitter.

Mr. P. C. Mitter: Mr. Joshi admits that for velocities of wind slightly higher than the current in a stream and blowing

in the same direction, the line of the greatest velocity in the same vertical plane, paralled to the motion, in a stream, is at a depth below the surface. Or in other words, he admits the parabola (curve of velocity) in a vertical plane, along the direction of flow of water, in a moving stream,—the axis of the parabola being below the surface. He is not evidently inclined to accept the above also in cases where the wind is several times greater than the current, say, for instance, in a hurricane. I state, however, that even when this is the case, the axis of the parabola, or the line of the greatest velocity is still below the surface. An extract which proves the result for such a contingency is subjoined:

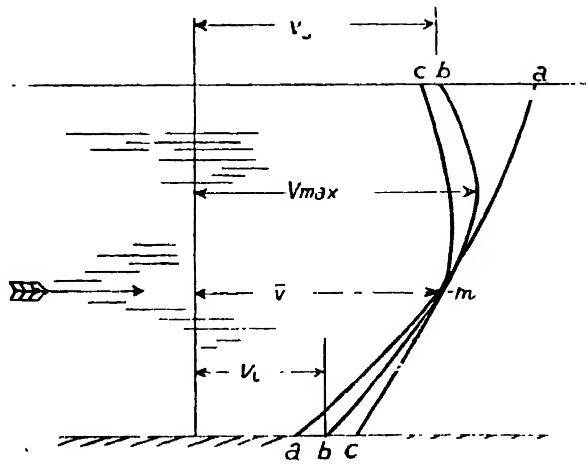
Influence of wind on the depth at which the maximum velocity is found.— In the gaugings of the Mississipi, the vertical velocity curve was found to agree well with a parabola, having a horizontal axis at some distance below the water surface, the ordinate of the parabola, at the axis, being the maximum velocity of the section. During the gaugings, the force of the wind was registered on a scale ranging from 0 for a calm, to 10 for a *hurricane.* Arranging the velocity curve in three sets (1) with wind blowing up-stream, (2) with the wind blowing down-stream and (3) calm, or wind blowing across stream—it was found that an up-stream wind lowered and down-stream wind raised the axis of the parabolic velocity curve. In calm weather the axis was at 3/10th of the total depth from the surface of all conditions of the stream.

It will be seen that the real motion of water in a stream is more complicated than what Mr. Joshi has taken.

As this does not upset, however, his exposition of the behaviour of frictional laws both in moving solid and liquid, I would suggest, that the complicated extra motion referred to above, of particles of water in moving stream, absent from Mr. Joshi's published paper, should be embodied in the discussion on the subject so as to make one complete whole. To Mr. Joshi, the writer of the first, preference in my opinion should be given for this supplementary treatment. Failing Mr. Joshi, others should be invited to do so either in the discussion or in a separate paper.

Mr. S. B. Joshi (in reply): Mr. Mitter insists that the greatest velocity is never at the surface whatever the strength of the wind blowing in the direction of the current. I do not feel happy to argue on the table a point which can only be settled between us on a riverside.

However in confirmation of my original statement I give below an extract from page 333 Art. 112—Distribution of velocity in an open channel—Gibson's Hydraulics, Fourth Edition.



The effect of the wind on the curve of velocities in a vertical section is indicated in the figure which shows the curves,

(a) With a strong up-stream wind,
(b) With no wind,
(c) With a strong down-stream wind.

It is found that although both the magnitude and position of the filament of maximum velocity is affected, that of the filament of mean velocity (*m* in the figure) is sensibly independent of the state of the wind...........etc., etc."

DISCUSSION ON

RAO SAHEB N. S. JOSHI'S PAPER ON LACEY'S THEORY & DECCAN CANALS.

(*This paper was published in Journal Vol. XIX, Pt. II, pp. 159-210*)

Mr. Greald Lacey, M. Inst. C.E. wrote : As an original contribution to hydrulic science the Author's paper is very disappointing. Reference is made to the "Lacey Theory" and inordinate pains is taken to show that the "Lacey Theory" does not apply to the Deccan Canals. The theory of the writer can best be understood by studying "Stable Channels in Alluvium," Procs. Inst. C.E., Vol. 229, and "Uniform Flow in Alluvial Rivers and Canals," Procs. Inst. C.E., Vol. 237.

It requires very little more than a superficial study of the theory of regime, as applied to channels in incoherent alluvium, transporting silt of the same alluvial grade, for it to be realised that conditions on the Deccan canals are very different. The Author quite correctly concludes that the Lacey theory does not apply to the Deccan canals. Unfortunately his handling of the Lacey theory is not very happy and betrays ignorance of the subject.

Appendix No. 1 of the Author's paper is a criticism of the Lacey theory as applied to channels in incoherent alluvium. The reference to "manipulation" of powers, and "arbitrary manipulation of unknown factors" leaves little doubt that the Author is not prepared to accept the Lacey theory even when applied to channels in alluvium. A paper such as the Author's is possibly not the best medium for criticism of this character.

The Author's paper may be briefly summed up thus:

(a) he demonstrates that the Lacey theory does not apply to the Deccan Canals,

(b) he suggests that the Lacey formulae as applied to channels in alluvium "do not agree mathematically"

and that before they can be accepted it is necessary to accept "arbitrary manipulation of unknown factors" to explain them,

(c) he foreshadows an original contribution of his own on the economics of design of Deccan channels.

The writer entirely agrees that the Lacey theory cannot apply to channels with rigid boundaries, and also fails to understand why the Author should have been at such pains to prove what is self evident. The remarks of the Author in respect of dimensions show that he fails to appreciate their significance. It is quite evident that the Author regards an appeal to dimensions on the part of the writer as merely a means of explaining discrepancies. Without regard to the merits or demerits of the writer's work recourse to dimensional analysis is in entire accordance with the contemporary technique of fluid machanics.

It would appear that the Author is entirely content with the equations of Kutter, or Manning. Now the Manning formula in metrical units is

$$V = R^{2/3} S^{1/2} / N,$$

and in this equation, to use the Author's words "the dimensions do not tally." Adopting the attitude of the Author it would be permissible to say of the Manning equation that it *cannot be accepted, as the dimensions do not tally* and an arbitrary manipulation of unknown factors is required to explain it.

The Author specifically refers to the well-known and fully established equation of the writer

$$P = KQ^{1/2}$$

and remarks "in this formula the silt factor does not exist at all and *still* the dimensions of the two sides of the equation are different."

This remark betrays a surprising ignorance of the dimensional problem. The Author appears to think that it is only when an equation includes the silt factor that recourse to dimensional analysis is justified, and that all equations which do not include the silt factor must "tally" on each side dimensionally. A typical example of an empirical equation of which the dimensions do not tally is the useful Manning equation.

It may be presumed that the Author has made himself familiar with the classic work of Osborne Reynolds, and the advances made by Nikuradse and Prandtl in producing dimensioned equations for the flow of fluids and gases in pipes. Effectively all contemporary work on the flow of water *involves* the "effects of gravity, kine-matic viscosity, etc."

The Author suggests that any tentative treatment of the dimensional problem by the writer is "not based on considerations of theoretical reasoning." The writer would suggest that the best method of studying the "Lacey Silt Theory" is possibly to read his original works. The writer will be interested in Mr. Joshi's eventual original contributions to hydraulic flow.

The Author, by referring to the Lacey theory in the title of his paper would appear merely to have sought a platform for destructive criticism of the work of another. The writer trusts that the next work of the Author will take the form of a constructive original contribution.

Mr. Ram Kishore : I have only a few words to say. I belong to U.P. Irrigation, and can claim some knowledge of Mr. Lacey's theory. I am sure it does not apply to Deccan canals such as those described by Rao Saheb Joshi. It applies only to channels in alluvium.

Mr. S. B. Joshi : The Author must be congratulated on the pains he has taken in compiling his paper. Unfortunately no one seems to have carefully examined the Mathematical argument behind Lacey's equations. On a careful study of Lacey's original Paper I have come to the conclusion that Lacey's Mathematical argument is fallacious, and his theory does not stand the elementary test of Mathematics and therefore need not be discussed in such detail as the Author has done.

Let us examine the Mathematical argument behind Lacey's theory. This is how Lacey argues to set out his equations :

$V_0 = 1{\cdot}17\sqrt{R}$, Kennedy Velocity expressed in terms of $\sqrt{R}$ by Lacey.

$\frac{V}{V_0} = \sqrt{f}$, Lacey's definition of silt factor as square of the ratio of actual regime velocity to V_0—The Kennedy Velocity for the same channel.

$\therefore$ $V = 1{\cdot}17 \sqrt{fR}$, Lacey's first general silt formula.

$\therefore$ For channels having same mean velocity but different silt factor and other dimensions $f\,R = f'\,R' = f''\,R''$.

If now Law governing wetted peremeters is deliberately assumed to be of the same nature as that governing hydraulic mean depths

$f\,Pw = f'P'w = f''P''w$, where Pw is the wetted peremeter.

Multiplying one equation by the other and writing A for the product R Pw

$Af^2 \quad A'f'^2 \quad A''f''^2$

He later shows by a graph that

$Af^2 = 3{\cdot}8V^5$

If the deliberate assumption that the law governing wetted peremeters is of the same nature as that governing hydraulic mean depths be correct, the equation expressing regime velocity in terms of Pw will be of the form

$$V = K \sqrt[3]{f\,Pw}.$$

$$\text{Because } \frac{Af^2}{Rf} = f\,Pw$$

$$\text{and } f\,Pw \propto \frac{V^5}{V^2} \text{ i.e. } \propto V^3$$

Therefore if 'f' for Kennedy velocity is unity, Kennedy velocity in terms Pw will be

$$V_0 = K \sqrt[3]{Pw}.$$

$$\therefore \frac{V}{V_0} = \frac{K \sqrt[3]{f\,Pw}}{K \sqrt[3]{Pw}} = \sqrt[3]{f}$$

This means that if Lacey had proceeded with an equation for velocity in terms of Pw instead of R, he would have defined his silt factor 'f' as under,

$$\sqrt[3]{f} = \frac{V}{V_0}$$

If both the 'f's. *i.e.* silt factors are the same (the 1st from the equations $fR=f'R'$ and the other from the equations $fPw=f'P'w$—and Lacey has taken them to be the same when he multiplies the two equations $fR=f'R'$ and $fPw='fP'w$ and gets $Af^2=A'f'^2$) we come to the absurd result,

$$\left(\frac{V}{V_0}\right)^3 = \left(\frac{V}{V_0}\right)^2$$

$$\left[\because f \text{ as co-efficient of R is } \left(\frac{V}{V_0}\right)^2 \right.$$

$$\left. \text{and as co-efficient of Pw is } \left(\frac{V}{V_0}\right)^3 \right]$$

$$i.e.\ 3 = 2.$$

If on the other hand the silt factors mentioned in the equations $fR=f'R'$ and $fPw=f'P'w$ are not the same and we write the equations as $FR=F^1R^1$ and $F_1Pw = F_1'P'w$ the product of the two equations shall give us $FF_1A=F'F_1'A'$.

But such an equation will not lead to the remarkable result arrived at by Lacey *viz.* $Pw \propto Q^{\frac{1}{2}}$.

Thus most of Lacey's equation and remarkable results fall to the ground.

Lacey's theory therefore cannot apply to any canals and there is therefore no point in devoting so much energy to show that it does not apply to Deccan Canals. Such an attempt unnecessarily leads others to believe that Lacey's theory at least applies to channels in alluvium which it obviously does not.

Regarding Mr. Gerald Lacey's contribution, the **Author** is glad that he has come forth to take part in the discussion and actually accepted that his theory did not apply to Deccan Canals. In fact it is gratifying to note that he considers this to be an obvious fact since Deccan-Silt is Non-coherent. Mr. Lacey appears to convey that collecting of such data was not necessary and it is probably because of this that he considers the Author's paper "*very disappointing as an original contribution to hydraulics.*" What Mr. Lacey forgets is that although he considers the fact of the Non-application of his theory to the Bombay-Deccan as apparent, his very supporters have betrayed him. Against what the

Author has been maintaining ever since the publication of Mr. Lacey's theory, Mr. Inglis, whose services in the formation of his theory have been accepted by Mr. Lacey, and who is known to possess perfect knowledge about soils and sub-soils of the Bombay-Deccan and the canals in that tract including the Silt conveyed by the same, has not simply tried to apply Mr. Lacey's theory to Deccan Canals, but has actually remodelled the Pravara Left Bank Canal on the basis of that theory. In fact Mr. Inglis has actually tried to fix the silt factor for Deccan Canals at 0·60 to 0·80, based on data for V, R and S. Either Mr. Lacey must therefore charge Mr. Inglis for not having understood his theory or he must ask the world to save him from his "Friends".

And Mr. Inglis is by no means the only person of this type. Mr. Montague of Punjab formerly Secretary, Central Board of Irrigation when criticising the Author's Paper on the "Economic Bed-Fall of Canals (in the Bombay-Deccan) "found fault with the Author's theory and formulae because they did not agree with Mr. Lacey's theory.

The Author had therefore to choose between (1) supposing that these two eminent Hydraulicians and a few others were wrong, or (2) that Mr. Lacey himself was not very clear in laying down his theory so as to clarify whether it applied to tracts like Deccan or not.

In either case therefore, collection of data and proving the inapplicability of Mr. Lacey's theory to Deccan Canals was a necessity and this explains the reasons which led the Author to do what he has done.

Regarding the fallacious position about Mr. Lacey's equations and the fact that the equations do not balance mathematically, Mr. Lacey has taken recourse to showing that even Manning's equation does not "tally" mathematically. Mr. Lacey is wrong in this. Manning's equation $V = R^{\frac{2}{3}} S^{\frac{1}{2}} \div N$ does easily tally, and $N = V \div R^{\frac{2}{3}} S^{\frac{1}{2}} = L^{\frac{1}{3}} \div T$.

The non-mathematical position of Mr. Lacey's equation lies in the fact that each of his equations shows different dimensions for his silt factor.

Thus *e.g.* in his equation. $V = \sqrt{f.R}$, the dimensions of his silt factor are $\frac{L}{T^2}$ Had the dimensions of his silt factor

remained the same in his other equations, there was no anomaly. Such is however not the case. His equation $Af^2 = V^5$ shows the dimensions of the silt factor to be $\frac{L^{0.5}}{T^{2.5}}$!!

In fact no two equations in Mr. Lacey's theory show the same mathematical dimensions for his silt factor. It is here that the foundations of Mr. Lacey's theory and equations crumble. As shown by the Author already the most glaring instances of this lies in the two sides of his equation $P = \sqrt{Q}$ not agreeing mathematically.

Mr. Lacey has obviously completely failed to understand the Author's treatment of the dimensional fallacy and his repeating the sentence.

"A typical example of an Emperical equation of which the dimensions do not tally, is the useful Manning's equation" leaves the Author to wonder whether Mr. Lacey cannot conceive that Manning's N can have certain fixed mathematical dimensions !! The fact is that the equation does balance, but that unlike Mr. Lacey's equation which has a separate story to tell and a new excuse to give for explaining the ever-changing dimensions of his "f", Manning's N remains unchanged. The replies given by Mr. Lacey on this point evince either perfect ignorance or more probably an uncompromising attitude.

There is ground for sympathy, when one finds Mr. Lacey thus chafing at finding his pet theory being accepted neither in Punjab nor in Sind nor in the Bombay-Deccan, where his followers and appreciators actually applied it and remodelled Canals on the basis of that. The reason for the Author's "*destructive criticism*" (as described by Mr. Lacey) is to be traced to the over-enthusiasm of his followers as explained above, who would not look to a theory for Deccan because it did not agree with Mr. Lacey's. Mr. Lacey will find the Author's theory for designs of Deccan Canals in his contribution "Economic Water-Depth of Canals in the Bombay-Deccan" a paper accepted by the Institution of Engineers (India) and in a few other publications of the Bombay Engineering Congress.

Regarding Mr. Ram Kishore's remarks, I am glad that (unlike other followers of Mr. Lacey in the Southern half of India) he agrees that Mr. Lacey's theory does not apply to the Bombay-Deccan.

The Author is obliged to Mr. S. B. Joshi for the glaring mathematical fallacy in Mr. Lacey's theory exposed by him. In fact the Author had shown the fallacious basic assumptions in Mr. Lacey's theory of the equations $f Pw = f'P'w = f''P''w$ in his articles under the Nom-de-plume "Magnet" in the Indian Engineering 1931-1932.

Having freed himself from the onerous task of proving and getting Mr. Lacey himself to accept that "Lacey's Theory" does not apply to the Bombay-Deccan and similar other tracts of igneous formations, the Author will now be able to make further headway with his work on "Canals in the Bombay-Deccan".

ELECTRICAL MANUFACTURING INDUSTRY IN INDIA AND THE SCOPE AND LINE OF ITS FUTURE GROWTH

BY

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Received June 24, 1939.

INTRODUCTION

The question of diversifying industrial and economic activities of the country on a planned basis has very recently attracted considerable attention from many responsible quarters. It is proposed here to review briefly a primary industrial activity in this country and to indicate the line and scope for its future growth.

PRESENT CONDITIONS IN INDIA

Electrical manufacturing did not exist in India twenty years ago. All that existed in this direction were the workshops attached to the power stations and other electrical concerns. The Indian Cable Co., Jamshedpur, the only major manufacturing concern in India was formed in 1920 with a capital of Rs. 30 lacs out of which 13½ lacs were subscribed in India. The difficulties met with by this company from its very initiation due to tariff inequalities, stock depreciation caused by falling prices, competition with the agents of foreign companies, prejudice against Indian manufacture etc. were so great that it could shake the confidence of the Indian people in technical industry.*

The effect of such early reverses is reflected in the present position of electrical manufacturing in India. Inquiries made by this department indicate that electrical manufacturing activities even in the initial stage do not exist in any part of the

*Report of the Indian Tariff Board, etc. (1928) p.p. 38—54.

country except in six provinces and one or two states.† The activity that exists is meagre and limited to the following products :

(1) *Electrical machinery :* The only activity existing in the country in this branch is the transformer winding undertaken by the Government Electrical workshops at Bangalore. Single phase transformers up to 100 K.V.A capacity can be manufactured. The winding section has a production capacity of 4 to 5 hundred transformers a year.

(2). *Electrical wires and cables :* Indian Cable Co., Jamshedpur, manufactures rubber, varnished cambric and compound insulated cables and flexibles in all types and grades ; silk and cotton covered instruments wires and strips; copper, copper weld and aluminium wires and strands of all commercial specifications.

(3). *Electric lamps :* Four factories, at Calcutta, Bombay, Agra and Bangalore deal in this kind of manufacture. One more is under construction in Sind. The production capacity in all these cases does not exceed a few thousand lamps per day.

(4). *Telephones :* These are being manufactured by the Government workshop at Calcutta. Telephones worth Rs. 1,75,000 were manufactured in 1938. No more black telephones necessary for the Post and Telegraph Department will have to be imported hereafter.

(5). *Porcelain Insulator.* Low tension insulators up to 13 K.V. are manufactured in India. The Government Porcelain factory, Bangalore, the biggest concern in the line, sends out insulators worth about 100,000 rupees annually. It is reported that the present Indian requirements in low tension insulators is mostly supplied by Indian companies.

(6). *Electric fans and other goods :* Workshops dealing in the manufacture of A.C. and D.C. fans, heaters, dry cells, torch light casings, electric light fittings, electric stands and shades, clocks etc. are springing up in the vicinity of big cities like Bombay, Calcutta, Madras, Lahore, Aligarh and Cawnpore. Information regarding these is scanty and is scattered in the official reports of various Governments.

† Punjab, U.P., Bombay, Bengal, Madras, Bihar and the state of Mysore.

(7). *Radio manufacture :* Manufacture of radio valves and apparatus does not exist although radio repairing workshops are increasing rapidly. A promising market exists for this kind of manufacture*. The Research Department of All-India Radio has developed special cheap sets for Indian conditions.

It must be remarked here that the manufacture in most of the cases mentioned depends upon imported raw materials such as sheet steel, special steels, electrolytic metals, copper bars, insulating materials, etc. which are not available in India and which cannot be profitably manufactured locally on a small scale. In some cases finished components which involve great technical experience and skill in manufacture are directly imported. The extent to which the Indain manufacturer depends upon foreign imports can be well appreciated from the fact that the Government Telegraph Workshop at Calcutta, with all its organization and resources, had to purchase from outside firms raw materials and components worth Rs. 100,000 to prepare telephones of the value of Rs. 175,000.

Co-ordination amongst various concerns does not exist; so that any attempts to improve manufacturing or commercial technique or to increase the standard of self-sufficiency of the industry are very closely circumscribed by the resources of individual concerns.

In other countries such co-ordination exists and is responsible for carrying out much useful work both in the technical (research) as well as the commercial field.† It is true that Government Department and scientific institutions exist in this country which can do much useful work in the field, but it is found that the Indian manufacturer does not know the exact nature of his technical difficulties, or having found them is not willing to seek aid from a public institution in a matter which he rightly regards as his commercial secret.

Thus while the progress of Indian Industry is very slow, foreign manufacturers are assiduously cultivating the Indian market by adopting a forward trade policy in this country.

* Import of Radio apparatus has gone up to to Rs. 48 lacs in 1937-38 as against Rs. 35 lacs in the previous year.

† In England for instance such organizations as B.E.A.M.A., E.L.M.A., C.M.A.; etc. exist. E.L.M.A. alone spent £200,000 in lamp research in 1938.

Experts are being sent out to India to study Indian conditions first hand and to secure and carry out contracts under personal supervision. The following import figures indicate the part played by various countries in the Indian electrical market. As the figures refer to the period between 1930 and 1935 the effect of the world economic depression which began in 1929 is also detected.

TABLE NO. 1.

Indian Imports of Electrical Machinery

			(Rs. 000)		
	1930-31	1931-32	1932-33	1933-34	1934-35
United Kingdom ..	18158	15007	12090	8603	12179
Germany ..	1675	1506	1037	1087	2124
Netherlands ..	48	123	37	136	55
Belgium ..	397	424	101	69	149
France ..	56	17	22	85	65
Italy ..	180	165	77	167	136
Japan ..	2	2	6	18	43
U. S. A. ..	2434	3644	1587	1689	1197
Total ..	23898	21626	15589	12742	16891

†TABLE NO. 2.

Indian Imports of Electrical Goods and Apparatus.

			(Rs. 000).		
	1930-31	1931-32	1932-33	1933-34	1934-35
United Kingdom ..	17402	11528	12151	13053	16244
Germany ..	4280	3290	3442	2521	3198
Netherlands ..	1487	1309	1102	1148	1300
Belgium ..	748	455	290	326	206
France ..	313	243	134	246	108
Italy ..	862	524	617	627	761
Japan ..	708	529	1681	1518	1675
U. S. A. ..	4373	3021	2660	2393	3059
Total ..	31061	22298	23420	23081	28120

† World Power Vol. 25 P. 71

CONDITIONS OUTSIDE

In the industrial countries abroad electrical manufacture has assumed a national importance due its being a basic industry. The table given below would indicate the rapidity with which the industry has grown during the last two decades in the case of three leading electrical manufacturing countries. The export figures account for something less than half the total electrical production of the countries.

TABLE NO. 3.

EXPORT OF ELECTRICAL MACHINERY AND GOODS

	1913	1925	1937	1938
U. S. A. ..	£ 5790000	16300000	23959000	21734000
Germany ..	„ 15887700	15900000	26708000	27132000
Great Britain ..	„ 7655700	17564000	18487989	21647048

Even predominantly agricultural countries like Australia, Canada, Russia etc. which have recognised the importance of the industry are making rapid progress in the field.

The keen international competition existing in the international electrical market has led to the following developments in the electrical manufacturing industry. (1) Co-ordination of the industry in the form of mergers and commercial associations or by way of state control with a view to avoid waste of money and labour inseparable from the existance of separate concerns. (2) Investment of large finances to secure and undertake large business on competitive basis. (3) Intensive research to save men and materials and to improve quality of goods. (4) Adoption of forward trade policies to secure international market. (5) Adoption of mass production methods where possible.

In countries where the indigenous industry is in its infancy State-support and special legislations have been found necessary. Legislations on following points may be mentioned in this connection. (1) Tariffs against imported goods. (2) Rationing of imports (3) Currency manipulation (4) Special commercial treaties (5) Raising of state authorised capital (6) State control over the industry.

FAILURE OF INDIAN INDUSTRY

In India there is a good market for some classes of mass production goods and for heavy electrical machinery. This market is rapidly increasing due to the industrial and economic development of the country, which is resulting in a diversification of its requirements. There are other considerations also such as cheap Indian labour, saving on freight, goodwill of the people etc. which would greatly help the Indian industry. But no attempt has been made so far to organise the industry on a large and systematic basis ; we may attribute the failure to the following factors.

(1) Want of sufficient experience and technical knowledge in organization of technical industry.

(2) Lack of trained specialists to maintain the industry.

(3) Shyness of the Indian capitalist to invest in a new technical field.

(4) Competition with well-established foreign firms in the home market.

(5) Lack of self-sufficiency arising out of the necessity of importing raw materials from abroad.

A speedy and effective solution of many of these difficulties can be obtained by organising the industry on a more scientific and national basis. A scheme for the purpose is outlined by the authors in the Report on the Development of Electrical Industry in India submitted to the National planning Committee by this Department.* In the present paper it is proposed to confine attention to the scope and direction of progress.

SCOPE AND DIRECTION OF FUTURE PROGRESS

In view of the present undeveloped state of industries in the country and the various disabilities outlined above, it would be a sounder programme if the task of developing the industry in all its necessary branches is spread over a number of years. This would allow the industry to train its own skilled labour and technicians and gather gradually experience and confidence in the new field. The industry should be divided in

* A Summary of this Report is published in the Electrician. Vol. 112 p.630; Current Science Vol. 8 p.338.

a limited number of specialist firms each one producing a number of complimentary products. The programme should begin with such factories as require minimum technical experience or skill.

If more than one factory manufacturing the same goods are opened these should be co-related technically and commercially. In compiling the following tables an attempt is made to indicate such specialist firms and the scope of their activity. The approximate value of goods recently imported to this country and falling under each head is also given side by side.

TABLE NO. 4.

A list of probable specialist firms.

Class A.

Branch.	Scope of activity.	*Approximate yearly import of goods in Rs. 000.
1. Electric goods ..	Fans, heaters, cookers, furnaces, fractional H.P. motors.	4500
2. Lamps ..	gasfilled and vacuum-lamps, bulbs, torches, automobile and lamps.	4700
3. Batteries ..	Batteries, accumulators electric carbons.	3000
4. Lighting accessories ..	Lighting accessories fittings, switch boards.	1100
5. Radio apparatus ..	Receiving and transmitting apparatus and components.	3500
6. Meters and Instruments ..	Various types of instruments.	1100

CLASS B_1.

1. Wires and cables ..	Insulated and bare copper wires and cables, telephone and telegraph cables.	9300
2. Transformers and Motors (Induction).	Transformers and induction motors (in first stages up to medium size.)	4000

CLASS B_2.

3. Prime mover plant	Steam boilers turbines and Hydraaulic equipment	Figures not available.
4. Generation plant	D.C. and A.C. generators and motors, Turbo-alternators, convertors etc.	5500
5. Auxiliary apparatus	Control and switchgear, protection apparatus etc.	4500

(* A round figure based on the average of the imports during 1935-36 and 1936-37 is given. Actual figures for these and other years are given in Table No. 6.)

It must be noted that in the absence of any first hand experience and knowledge necessary in connection with the starting of new factories, some of the factories mentioned above can be erected only with the help of some well-established foreign firm which would be prepared to co-operate on suitable conditions. Such co-operation was necessary in the case of every country (Australia, Canada, Russia, Japan, Eire etc.) that has recently preceded India in the field. Co-operation on the points mentioned below may be found essential.

(1) Erection of factories equipped with up-to-date manufacturing equipment.

(2) Lending of experts and engineers during initial period.

(3) Training Indians with a view to taking up important positions in Indian factories.

(4) Exchange of technical and if possible commercial experience.

There will be some difficulty in arranging co-operation on this basis; but advantage can be taken of international competition to secure the most favourable terms possible in return for commercial concessions extending over some fixed period.

Manufacture of goods enlisted in class A and B_1 should be taken up first, since this affords some special advantages :—

(1) These factories can be started on a small or medium scale initially and hence the financial investments involved will not be large.

(2) Some factories on these lines are already in existance and their experience can be utilised in undertaking the enterprise on a broader and a more scientific basis. Existing concerns can also be thus amalgamated with the new programme.

(3) Technical knowledge, experience and skill required in case of this type of manufacture is less than in the case of of manufacture of type B_2.

(4) These goods are produced on mass-production scale and do not involve rapid changeability of manufacturing equipment as in the case of specialised manufacture.

(5) The local market for this type of goods is larger and it does not necessiate shouldering of large financial responsibility to secure or supply it.

(6) Experience of the manufacturing factories already working in the line, though without sufficient financial or technical resources, justify further activity in the field particularly if it is taken on a more organised basis.

(7) Starting such factories would help building up of auxiliary industries manufacturing raw materials (such as copper rods, sheets steel, insulation etc.) necessary for the industry on larger scale.

(8) It would stimulate technical enterprise and help the industrialist and the engineer to gather experience in the new-field and train up skilled workmen and technicians in the line.

The following Table gives an idea of the results obtained by Australian manufacturers who undertook manufacture of electrical goods and light machinery very recently with the help of English firms and in co-operation with the Government.†

† Trade and Engineering (May 1935) p. viii.

*TABLE NO. 5.

Australian Electrical Manufacture.

Item of manufacture.	Years.					
	1930-31		1932-33		1933-34	
	Value of out put £000	No. of employees.	Value of out put £000.	No. of employees.	Value of out put	No. of employees.
1. Electrical installations, cable and apparatus	2161	4098	2562	5055	3131	5774
2. Wireless apparatus	560	908	1358	2263	1589	2625

These results were obtained, it must be noted, during the period of economic depression, which started in 1929.

Manufacture of Class B_2 type of goods can be delayed for some time and be undertaken after class A and Class B_1. factories have successfully worked for some time. This would create the necessary background for the class B_2 type of large scale industry involving a great amount of specialization and technique and also huge financial reponsibilities. The programme on this point can be considerably accelerated if various power development authorities in India co-ordinate their demands and create a surer and a more specified market for machinery. In fact since the big power companies and governments are the main customers of this kind of goods, it is desirable that these should be primarily concerned with the development and growth of this kind of manufacture. At the same time it cannot be forgotten that no single organization or Government would be ready to shoulder the responsibility of starting a new basic industry which has to depend upon the whole country for its market and resources. Considerations relating to financial and technical limitations, stabilization of markets, standardization of designs, etc. would come in the

* World Power. Volume. 25.p.193.

way. Probable solution of the problem seems to lie in the creation of a Central Development Board, representing all the electrical interests in the country. This Board should be responsible in chalking out a general programme of development and for sponsoring and guiding new electrical power schemes. It should also co-ordinate the manufacturing side of the Industry with the supply side.

In absense of such a Board, a useful plan of work would be to collect sufficient information regarding immediate scope in manufacture, which would throw light on the technical and economic aspects of such ventures. The interested public authorities can co-operate and with the help of existing scientific institutions, where facilities for specialised work are available, collect the necessary information. Such work would be useful if a planned scheme comes into existence through the co-operation of various public bodies. Otherwise the information can be placed in the hands of private industrialist whose lack of enterprise to-day seems to be mainly due to his ignorance in new technical fields. Information on the points such as the following would be useful.

(*a*) Scope of manufacture. 1. Reliable figures concerning import and consumption of any particular product or a set of complimentary products. 2. Their chief markets. 3. Their specifications 4. Possibility of future development of their market. 5. Particular locations that afford special facilities for opening a factory manufacturing such goods.

(B) Technical information.

1. Raw material necessary for manufacture of such products and their availability in India. 2. The nature and cost of economic and simple type of equipment necessary for manufacture, taking into consideration questions of efficiency, first-cost, skilled labour etc.

(C) Previous experience.

1. Any useful information regarding such manufacture if previously undertaken in this country. 2. Comparision of indigenous products with foreign makes. 3. Suggestions regarding scope and methods of improvement.

It is true, it is too much to expect such information from public bodies, but it must also be remarked that under the present undeveloped condition of the industry unless such authentic information is forthcoming there is little hope, at least in the initial stages of purely private interests venturing in a new field.

TABLE NO. 6.

INDIAN IMPORTS OF ELECTRICAL GOODS AND MACHINERY.

(in Rs. 000).

(A).

Item.	1924-25	1929-30	1935-36	1936-37
Control and switch-gear ..	3770	3830	4435	4628
Generators, alternators and Dynamos	3300	9400	2183	3474
Motors	4260	4400	4235	3830
Transformers	1450	1860	1900	1914
Turbo-generating sets ..	730	800	766	963
Other types of machinery ..	6430	8790	7026	9331

(B) Electrical Goods and Apparatus.

	1924-25	1929-30	1935-36	1936-37
Electric fans and parts ..	2540	3940	3251	3613
Electric wires and cables ..	6230	1530	9351	9415
Telegraph and telephone, instruments and apparatus ..	1190	540	1791	1911
Electric lamps and bulbs ..	1720	4060	5112	4480
Batteries	690	1370	2061	2339
Electric carbons	70	290	215	203
Accumulators	860	2590	757	508
Lighting accessories and fittings	1340	1690	811	692
Meters	640	930	1046	1212
Other sorts of electric instruments	150	250	261	809
Electro-medical apparatus ..	90	430	499	392
Switch Boards	470	290	414	270
Unnumerated	3250	5700	3640	2990

The Institution of Engineers (India).

RONTGENOLOGY IN REINFORCED CONCRETE

BY

Dr. M.A. Korni, Member.

In the year 1895 Wilhelm Konrad Rontgen, after many experiments succeeded in penetrating solid bodies with X-rays thus rendering them transparent. The phenomenon was soon taken up by the medical profession in aiding diagnosis. Later on it was used for illuminating fabricated products in order to substantiate the fineness and coarseness of their structure. It proved so successful in detecting faults and defects and their causes that it became a great boon to the steel welding technique which was held back for a long time owing to the inability of examining the alliance between two pieces of iron or steel. Nowadays the use of X-rays in steel welding is as popular as it is in medicine. In the same way in Reinforced Concrete Engineering there is a lot of uncertainty as to the quality of the work executed. Nothing is known as to the behaviour of hookbars, overlapping joints or the appearance of various cracks. The necessity for economy in Europe has forced builders to abandon overlapping joints and to use welded steel instead. As X-ray examination was already well-established in steel welding, it was soon realised that it could also be applied to welded steel when covered with a thin skin of concrete. In reinforced concrete structures the steel is generally covered with concrete to a depth of 1″ to 1½″ only. With the perfection of the X-ray apparatus, it was easy to detect faults in the structure and a complete judgment could be formed as to the causes of failure. For example an X-ray examination is demonstrated on a beam with a fine crack (see plate 2). The cause of this crack was the subject of a great debate as the designer insisted that it was due to mistakes made at the time of execution. A skylight (see plate 2, fig. 1) was built upon the beam in question which was part of a roof. The

X-ray photograph showed that the position of the steel in the beam (plate 2, fig. 2) was not quite the same as shown in the drawings. Further, it was discovered that two bars "a" which should have taken off the tensile stress from the concrete were missing (plate 1, fig. 3). There were not sufficient stirrups and the anchorage of the tensile bars was poorly executed. The bars should have been bent in the form of a hook and not of a bend as it appears in X-ray photo.

The modern School of Physics have so far discovered the following rays which are placed in order according to their wave-lengths :—

Wireless Telegraphy	10^{9}—10^{8}—10^{7}—10^{6}—10^{5}
Hertzian Waves	10^{5}—10^{4}—10^{3}—10^{2}—10^{1}—3
Unknown Waves	3 to $10^{-0\cdot 8}$
Heat Waves	$10^{-0\cdot 8}$ to $10^{-2\cdot 3}$

Waves of the visible light rays between $10^{-2\cdot 3}$ & $10^{-3\cdot 0}$

Ultra Violet Rays	$10^{-3\cdot 0}$—$10^{-3\cdot 1}$
Invisible Light Rays	$10^{-3\cdot 1}$—10^{-6}—$10^{-6\cdot 5}$

Rontgen or X-Rays from $10^{-6\cdot 5}$ to $10^{-6\cdot 9}$

Gamma Rays	$10^{-6\cdot 9}$ to 10^{-8} (Plate No. 3).

The waves are measured in millimetres and indicated by Lambda.

From the above table it will be seen that X-rays are placed between invisible light rays of the ultra violet realm and Gamma rays. These rays are rays of radio-active matters or substances.

The length of the wave is measured from $\frac{1}{10}$ and further up of several Angstrom.

One Angstrom is equal to $\frac{1}{10,000,000}$ millimetre $= 10^{-7} =$ 1 AE

The tabulated rays are also called electro-magnetic rays as different from the Cathode rays. In the practice these are produced in the following way :

The end of a Cathode wire is made glowing and subjected to a flow of electric current of high voltage, creating therewith fast moving electrons. These electrons when striking a target produce X-rays. X-rays like the Gamma Rays are not deviated by magnetic or electric fields. The discovery of crystalline diffraction made it apparent that the X-rays can behave as light waves of very high frequency. X-rays have the property of rendering solid bodies transparent to a certain extent due to the penetration of the rays.

The intensity of penetration depends on three factors : (1) Atomic weight, (2) Depth or thickness of the solid body, and (3) The wave-length of the X-ray. Therefore, as the absorption of the X-rays depends on the atomic weight or thickness of the solid body, the greater the atomic weight or thicker the object the greater will be the absorption and *vice versa*. The intensity of penetration of X-rays through substances of different densities can be defined as follows : The ray that can pass through a lead plate of 0·07″ thickness, will also be able to penetrate a cast iron plate of 0·06″ or a cement slab of 3·9″ in thickness. Lead is a metal offering great resistance to X-rays and is, therefore, used in X-ray technique as a screen.

The wave-lengths Lambda are also in direct proportion to the penetration or transmission velocity "v" and indirect to the frequency "n" and therefore can be equated as below :—

$$\text{Lambda} = \frac{v}{n} = \frac{\text{Transmission velocity}}{\text{Hertzian frequency}}.$$

From the above it appears that the illuminative strength of X-rays being a function of the frequency and of the density "d" of materials, when put into action through materials made up of different densities it will produce different shadows on a photographic film. The question is what should be the grade of the two shadows to enable the eye to distinguish one from the other. For example in a reinforced concrete block of an average specific weight of concrete $d=2$ and its aggregate consisting of (1) Sand of a density $d=1·6$ to 2, (2) Cement $d=0·8$ to 2,

(3) Granite $d=2{\cdot}5$ to $3{\cdot}1$, (4) Steel $d=7{\cdot}8$, if the steel is embedded deep in a very thick concrete say 20", the X-rays will produce no difference in shadows between concrete and steel. From the above table of densities we cannot also expect any designs of shadows owing to sand, cement and stones being of a density similar to concrete. The photograph of X-rayed concrete of 1 : 2 : 4 mixture shows an uniform black shade, but the practice has proved that we may always expect shadows differing between different qualities of the same mixture. Dr. Phil. Max Weidemann who tried to account for the mysterious behaviour of X-rays not revealing the shadow of steel deeply embedded in concrete, in the course of his investigation drew up a valuable table of X-ray penetration in concrete from 4" to $15\frac{3}{4}$" thick in relation to the electric current which can be measured in milli. amp. per sec. We will return later to these values (see plate 4).

Through experiments it has been found that X-rays passing through a solid body with the intensity of I and I' and the ratio $\frac{I}{I'}=\frac{1}{2}$, the grade of the darkness of the shadows left on an X-ray photograph, will be s and s', amounting to a ratio $\frac{s}{s'}=\frac{1}{1{\cdot}72}$. It always comes to the same if an X-ray passes through two different objects of the same thickness, but of different atomic weight or density; and with a ratio of density $\frac{d}{d^1}=\frac{1}{2}$ or the ratio of thicknesses $\frac{t}{t_1}$ of the same atomic weight $=\frac{1}{2}$, the shadow ratio will result in $\frac{s}{s'}=\frac{1}{1{\cdot}72}$ $=0{\cdot}563$. The minimum difference in shadows to enable measuring is $s'-s=2\%$ and this is obtainable by X-raying substances having a shadow intensity of $s=0{\cdot}714$ and $s^1=0{\cdot}7$.

TECHNIQUE OF X-RAYS.

The process of X-raying is simple when the density of the solid body is known and the available voltage of electricity is appropriate. There are also factors necessary for getting a successful X-ray photograph, which will have to be considered. The general process can be described as follows :—

The surface of the object is placed before the Rontgen X-ray tube. On the opposite side is an impermeable lead

screen or an impermeable box containing an X-ray film. Plate 5 shows a diagrammatical arrangement for X-raying a block of cement 16″ thick.

The X-ray tube as shown in the photograph (plate 1, fig. 2) consists of a glowing wire-cathode and of a metallic plate-Anti-cathode connected with the poles of the high voltage electric current. The electric current passes with great velocity from the negative pole of the circuit on which the cathode is connected to the positive pole to which is switched the Anti-cathode.

By making the wire glowing with the aid of electricity of high velocity, electrons are borne, which are made to strike a metallic target-Anti-cathode causing a bouncing energy. A part of the energy borne by this about 3% is transformed into X-rays and the rest into heat. It is obvious that due to the great heat generated the Anti-cathode has to be provided with an effective cooling system. As the intensity between the poles of the cathode and Anti-cathode is subject to various differences, it is plainly seen that the wave-lengths are increased or decreased according to the ratio already mentioned.

$$\text{The wave-length Lambda} = \frac{\text{Velocity}}{\text{Frequency}} = \frac{v}{n}.$$

As the velocity of electro-magnetic rays in a vacuum space is constant and equal to 300,000 Km. per sec. = 186,000 miles per sec. it is obvious that the wave-length is only a function of the frequency. Since X-rays are not visible to the eye but make solid bodies transparent, we have to depend on shadows produced on photographic films. It has been mentioned above, that a successful X-ray photograph depends on many factors, one of the most important being the appropriate severity of harshness of the ray, which is a matter of technique and another is the time of exposure. The ray harshness is dependent on the magnitude of the intensity of the electric current applied. As regards the time of exposure, this also depends on the strength of the voltage. The greater the voltage the less the time needed for exposure, but high voltage also increases the scattering of the rays which affects the contrast of the shadows on the photograph. Direct or alternating current of low intensity can be made use of by means of different special outfits in the electric circuit. As per Greinach circuit diagram (plate 6) an

alternating current of a pressure between 110 and 360 volts is transformed to a still lower pressure for heating the glowing-wire and as for the Anti-cathode it is increased to 500,000 volts. The conversion into high pressure is only possible for alternating current. The Greinach circuit therefore consists of two condensers and two converging tubes. The photograph (plate 1, fig. 4) shows a complete outfit fixed in a railway carriage of the German States Railway built by the firm R. Seifert in Hamburg. Siemens & Halske have constructed a portable X-ray outfit for 200 kV. which can be transported to different places by two men only. A detailed description of various types will follow.

Concerning the observations of densities in concrete, although the technique of X-raying has been much improved there is still much speculation about the correct judgment of X-ray photographs. It is also of importance for a successfully informative X-ray photograph, to have the preliminary knowledge of the thickness and density of the object which differs from the thickness and density of a sample or pattern of a standard. We know that the density of concrete varies with every mixture and the manner of its fabrication. Assume that an X-rayed standard concrete of a density 2 offers a shadow strength say S. The dimensions of this standard sample are known. An X-ray photograph of a new block of concrete but somewhat thicker will present when X-raying a shadow of a strength S_1. If the intensity of radiation and the time of exposure and the focal distance of X-ray tube from the photographic film is known, the density of the new concrete can be found and measured if the Widemann table is used. See Table No. 4. The conditions for using this table are :—

The X-ray tube has to be at a distance of about 20″ from the photographic film of Agfa's X-ray special make.

The X-ray tube must be of 0·7 Activa-Metalix construction.

Assuming "D" is the thickness or depth in cms. of the new block

"d" a density which differs from the standard density=2

"S" is the strength of its shadow

"dS" is the difference of these two shadows expressed in %

and it is near the smallest recognisable shadow which is $ds = 4\%$.

The difference in density can be found from the following equation :

$$d = \frac{ds\%}{72} \quad \frac{d}{D_{oo}} \quad HWS$$

Whereas d and D signify the density and thickness of a standard concrete block ;

HWS signifies a factor appropriate to concrete of a medium layer measured in cms.

This formula can also be used for calculating the density of any concrete if the intensity of darkness and shadows $\frac{S_1 - S_0}{S_1} \times 100$ does not exceed 168%.

As regards the amount of X-raying expressed in milli-ampere-sec. of current to be used for different thicknesses of concrete blocks this can be found in Table No. 4. In the case of the density being different from the standard block = 2 the table value has to be corrected by a multiplicator $10^{\left(mD \frac{d_1 - d}{d_1} 0{\cdot}434\right)}$

whereas $m = \frac{603}{HWS}$.

The table below shows the values of HWS for concrete and steel for different Kilovolts of current :—

kV.	100	120	140	160	180	200
HWS for concrete ..	1·2	1·35	1·05	1·78	2·10	2·00 cms
HWS for steel ..	0·11	0·16	0·25	0·33	0·43	0·57 cms

With the help of the formulae above it should not be difficult to predict the possibility of X-raying steel embedded to a certain depth, but in reality it only materialises for very narrow apertures which render the compass of the rays very small.

It also offers great difficulties when tracing the existence of steel bars embedded 14″ deep in a concrete block of 16″ or 40 cms. thickness. It has been found that without applying a device for eliminating the scattered rays the photograph is of uniform shadows, from which the presence of the steel bars

could not be detected, although the estimated shadow degrees as per above formula should have made them visible ; the estimated penetration intensity for an electric current of 200 kV and as per intensity of shadows being near 160% the HWS for concrete was found to be 18 cms. and for steel 21½ HWS cms. The reason for the non-visibility of the steel is probably that the difference, which is about 3½ HWS, is too great, as practice has shown that the maximum difference should not exceed 2½ HWS. To avoid the X-raying of doubtful depth of steel the X-raying tube should be placed at an angle as shown in plate 7. There are also means of making stereoscopic photographs from which it is easy to judge the distances of steel reinforcements. Plate 1, fig. 1 is a stereoscopic X-ray photograph of a column 6″ thick. The electric current used for this X-raying was 110 kV and 6 mA strong. The focus distance was 33½″ and the time of ray penetration was about five minutes. kV is to be understood as Kilo Volts or 1000 volts, and mA = Milli-ampere.

The same method was used in X-raying the railway shed beam (see plate 1, fig. 3) which was of a very great depth, and it was only possible to obtain readable X-ray photographs by X-raying various surfaces of the beam under different angles as shown in plate 8. The surfaces 1 to 4 were placed horizontally to the X-ray tube. The surface 5 was placed in a vertical position and surfaces 6 and 7 under different angles.

The electric current used was 155 kV and 4mA.
The focus distance was made to be 35½″.
The size of the photographic films was 11¾ × 15″.

The time of X-ray exposure was for the surfaces :—

1 to 4	..	1 minute.
5 to 7	..	8 minutes.

The angle of the X-ray tube fixed for 1 to 5 was 90 and 6 to 7 = 45.

The depth of the beam	..	25½″
The width of the beam	..	6¼″

It will be very one-sided to speak only on X-raying in Reinforced Concrete structures, as other branches of engineering would also be interested in this method of quality examination. The author of this paper knows of :—

Equipments for coarse structure examination.
Equipments for fine structure examination.

Photograph No. 9 shows an X-ray examination of a boiler shell with the ray beam projected from the interior outwards. This is a coarse ray examination. Another example is shown in photograph No. 10, a radiograph of propeller of light metal with internal bracing.

The coarse X-ray examinations have proved to be useful in foundries (light metal pressure die castings). An X-ray plant enables the detection of cracks, occlusions, cavities, porocity, etc. while in welding, root and bending flaws and occlusions, in the construction of high pressure cylinders, rivet holes, cracks and corrosive effects, etc.

The following equipments for coarse structure work are on the market :—

Siemens & Halske Transportable X-ray for 200 kV—8 mA.

Siemens & Halske Transportable X-ray for 250 kV an 10 mA.

Siemens & Halske Stationary X-ray for 120 kV—10 m

Transportable X-ray Equipment 120 kV—10 mA.

The stationary X-ray plants are working at the higher potentials.

Transportable high power plants are meant for use in factories and on erection sites.

The transportable X-ray equipment for 8 mA and 200 kV (see plate 16) is used in various heavy industries such as ship yards, steel works, etc. This equipment is impervious to the effects of chemicals and such severe atmospheric conditions as humid air, industrial fumes, rain, etc. As all insulated surfaces are isolated from the air, this particular equipment is especially suited to tropical climates and can also be safely operated at high altitudes. The high operating voltage is generated in what is known as Villard circuit which supplies the X-ray (plate 10, fig. 2) tube with pulsating D.C. potential. By means of a specially patented construction of the high tension cables, their inherent capacity is used for doubling the transformer voltage.

The high tension generating circuit consists of 2 symmetrical transportable units, each of which produces a maximum potential of 100 kV against earth. The tube and tube-holder

are completely protected against high potentials and stray rays. In plate 13 is to be seen the high tension generating tanks "H_1" and "H_2".

1 Control unit marked with "HK."

1 Tube stand together with holder "R."

1 Tube stand "St."

1 Oil pump "P."

The equipment is purposely sub-divided into various units so as to make it possible to set up the plant on all kinds of awkward sites such as the galleries of large boilers, on railings of ships, bridges, tunnels and on steel structures. The plant is supplied with two 30′ high tension cables which are quite sufficient for all practical requirements. Owing to the special connecting units the high tension cables can be connected without difficulty to the transformer, and tube-holders, and in the latter case it is not necessary to remove the tube from its housing.

The tube-holder is adjustable as regards height and allows the tube to be rotated about its transverse and longitudinal axis. The stand legs are collapsible, thus permitting the stand to be passed through boiler manholes. By erecting the tube inside a boiler shell the Rontgen-rays can be projected outwards from the interior, thus producing photographs of screen images perfectly free from distortion due to the fact that the tube is rotatable round any axis. The direction of the rays can be adjusted or altered as required. Owing to the ease with which the stand and tube-holder can be adjusted to various positions, those parts of a test piece, which are of primary interest, can be more easily brought within the range of the rays. This fact is extremely important when considering the examination of bridge beams, marine and similar engine shafts, steel building frames, locomotive and automobile wheels and axles, aeroplane wings and control surfaces, and plate walls and rivetted seams of high pressure cylinders, etc.

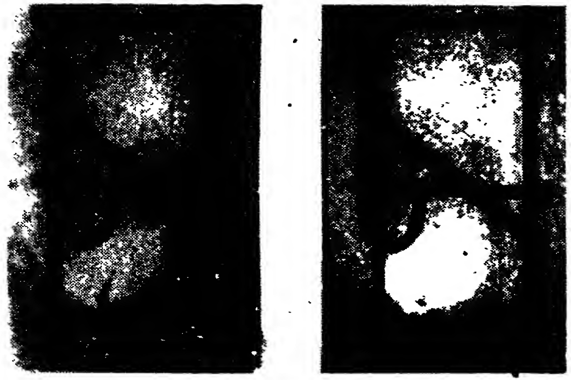
The tube that is used in this equipment is a special X-ray tube (see plate 10, figs. 3 & 4 designed by Siemens & Halske). The Anode consists of a copper cylinder "3" in the side of which is fitted a ray window "5" of thin metal foil. The end of the

cylinder which faces the glowing spiral "2" terminates in a small opening through which the electrons produced at the cathode "1" pass on their way to the target "4" where the collision with the target results in the generation of X-rays. Owing to the thickness of the copper cylinder, rays can only pass through the special window "5". The power of penetration of X-ray of this plant is through a thickness of 3 3/16 inches iron, 2 inches copper and brass, 7⅞ inches aluminium. The stationary type of X-ray is so designed that it can allow X-ray penetration in greater thicknesses of the mentioned materials, but we find them in use in several countries for systematic examination of light metal die casting, pressing and malleable iron parts etc. The equipment is also useful for Customs House examination of suspected bales and package without opening them.

CONCLUSION

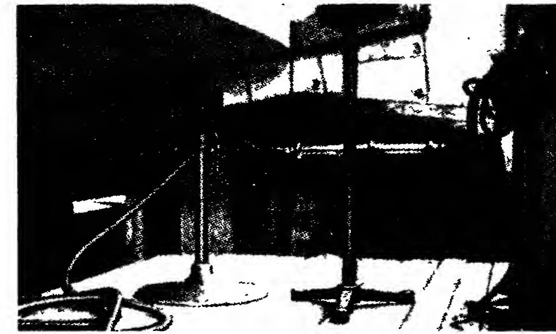
The possibilities of examining qualities of material, work, the location and nature of defects in reinforced concrete as well as in any other branch of Engineering, is not only extremely helpful but should be made compulsory on any construction where a deterioration of part of a machine, or badly fabricated joints etc. not visible to the human eye—can endanger human life. The X-ray photographs of different weldings which are applied to the modern constructions of great importance, as illustrated below do not need further explanations, but it is evident that the joint "1" (plate 11, figs. 4, 8 & 10) does not offer much factor for safety and could only have been discovered by X-rays. There are many unsolved cases of accidents in India the causes of which could only have been exposed by X-rays If X-ray examination had been carried out on the various mobile parts and immobile parts involved in the railway disaster at Bihta, we would have had a real explanation of the accident. As it is, we are still in the dark. Unfortunately the Railways Technical Authoritative Departments in India do not possess a single X-ray apparatus and have never given a thought to the usefulness of one. It is to be hoped that this paper may induce the leading Technical Authorities and Factories to take up this method of structure examination, when they realise the necessity of it in all branches of Engineering. The North Western Railway were for a time

PLATE NO. 1



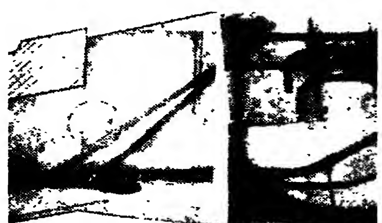
X.Ray Photograph of a column. Note the Nails of the Shuttering lost in the concrete. The White Spots are the indication of Scaling of concrete when the Shuttering was removed.

FIG. 1



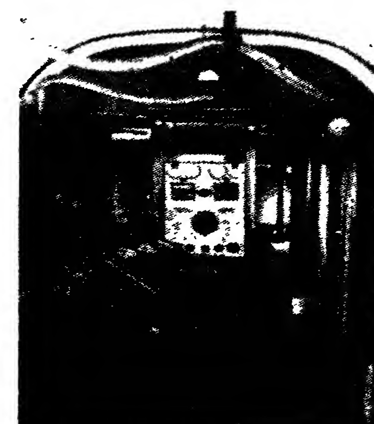
X.Ray Equipment for examining the Beam of the Railway Shed.

FIG. 2



X.Ray Photograph showing the position of Steel in the Beam of the Railway Shed.

FIG. 3



X.Ray Equipment attached to Railway carriage in Germany.

FIG. 4

PLATE NO. 2

RAILWAY SHED BUILT IN 1909 IN HANNOVER - LINDEN

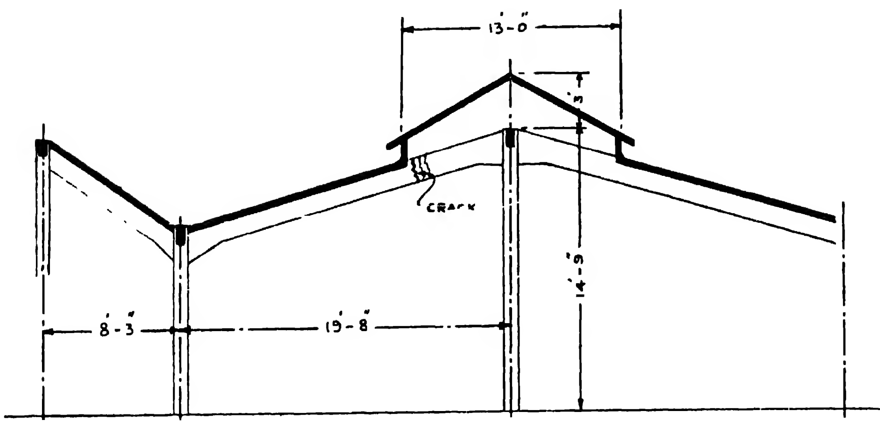
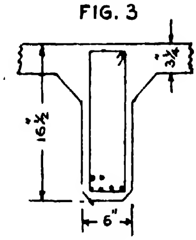


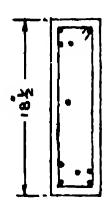
FIG. 1

FIG. 3



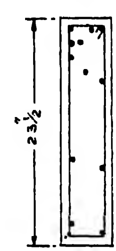
SECTION AB

FIG. 4



SECTION CD

FIG. 5



SECTION EF

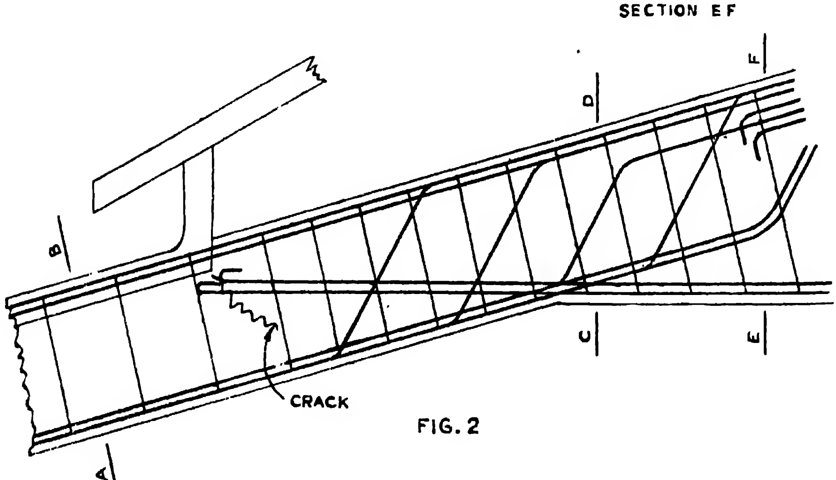
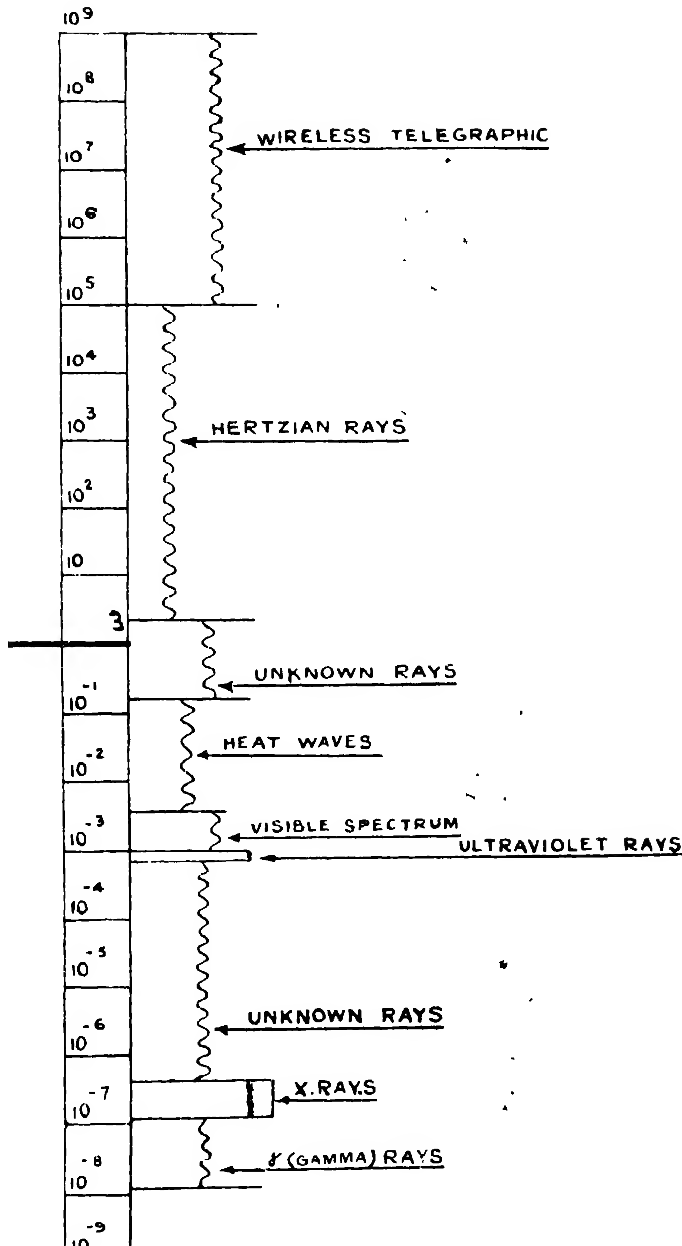


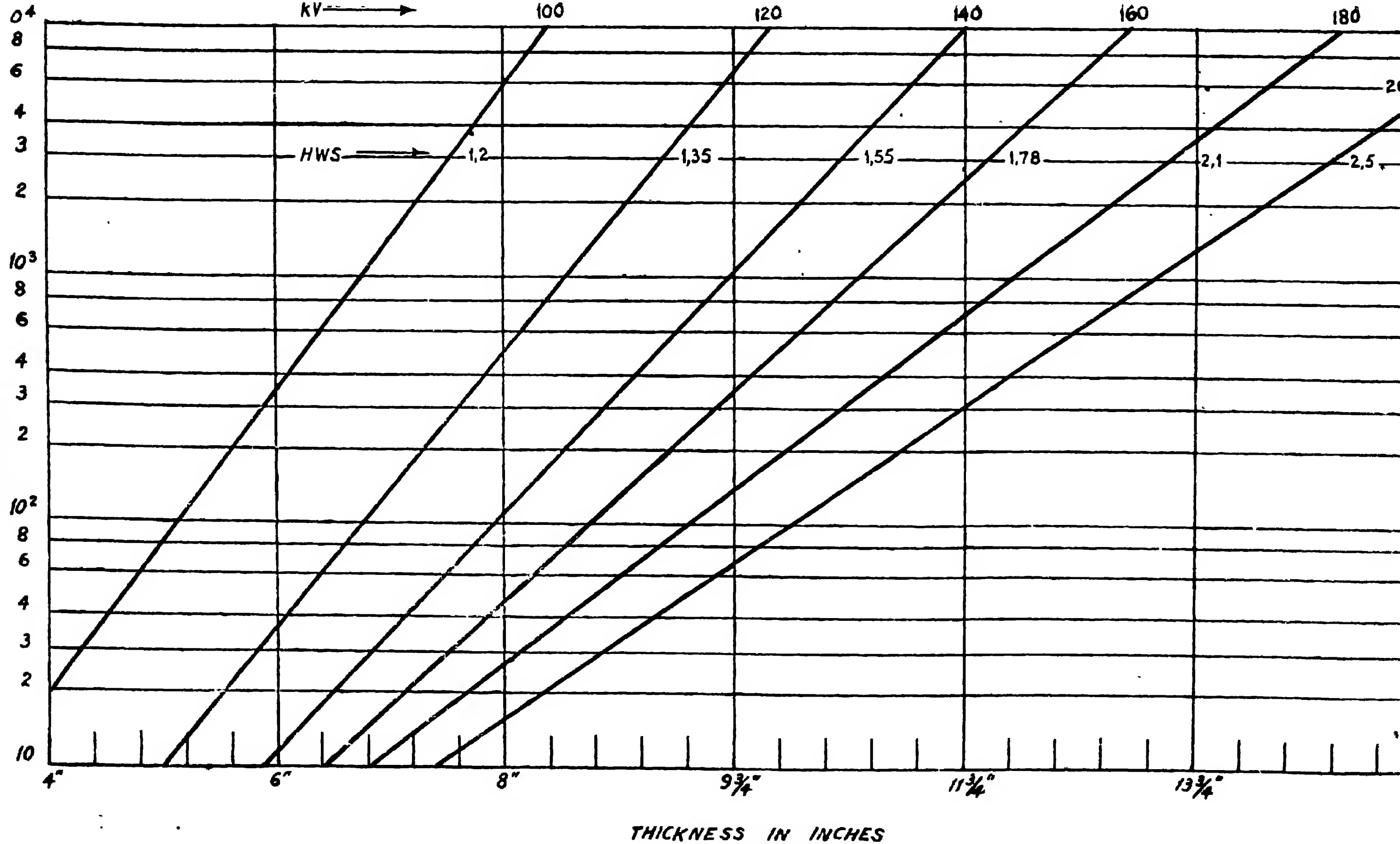
FIG. 2

PLATE NO. 1

WAVE LENGTHS OF ELECTROMAGNETIC RAYS

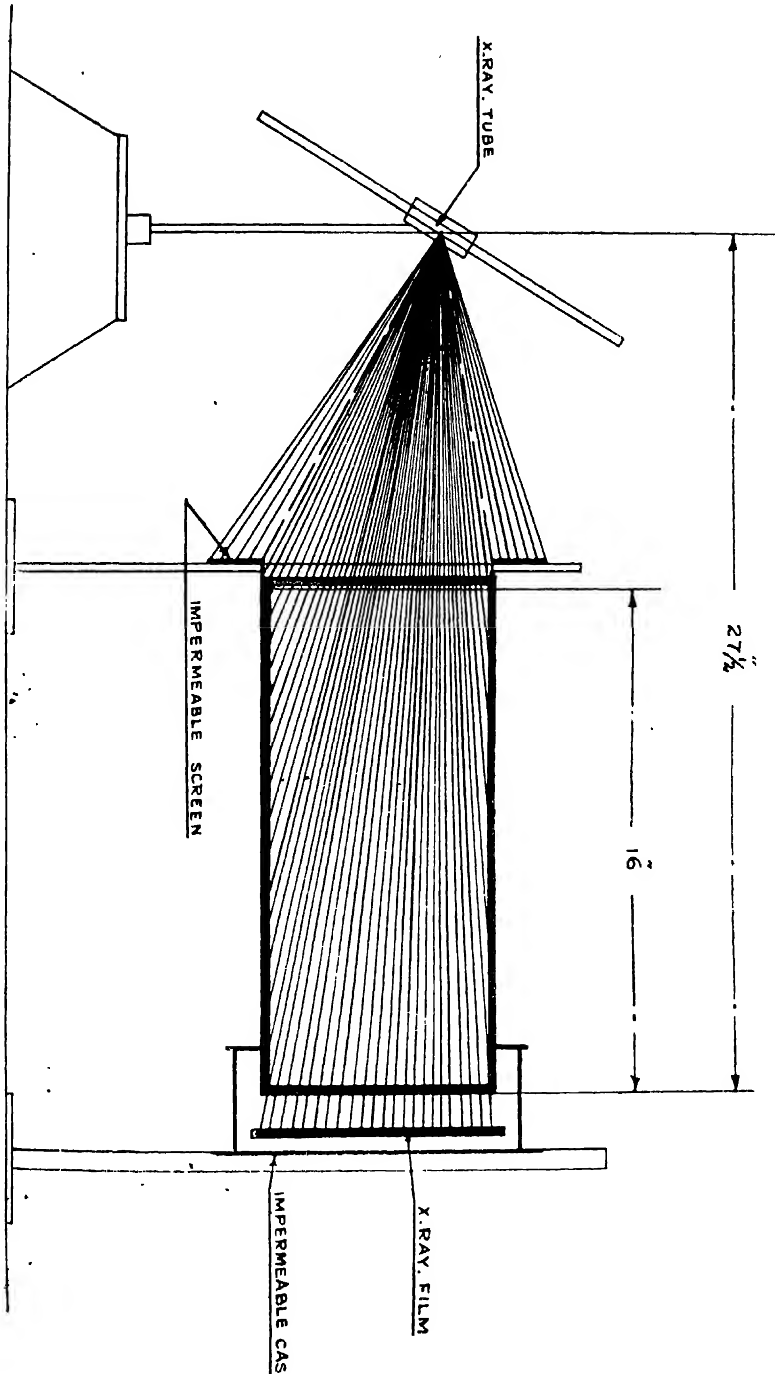


[redacted]



[redacted]
m A SEC
10
10^2
10^3
10^4
2
3
4
6
8
KV
HWS
100
120
140
160
180
200
1,2
1,35
1,55
1,78
2,1
2,5
4"
6"
8"
9¾"
11¾"
13¾"
THICKNESS IN INCHES

PLATE NO. 5



DIAGRAMATIC ARRANGEMENT OF X.RAY'ING A 16" CONCRETE BLOCK

DIAGRAM OF ELECTRIC CURRENT CIRCUIT FOR AN X.RAY EQUIPMENT
AS PER GREINACH SYSTEM

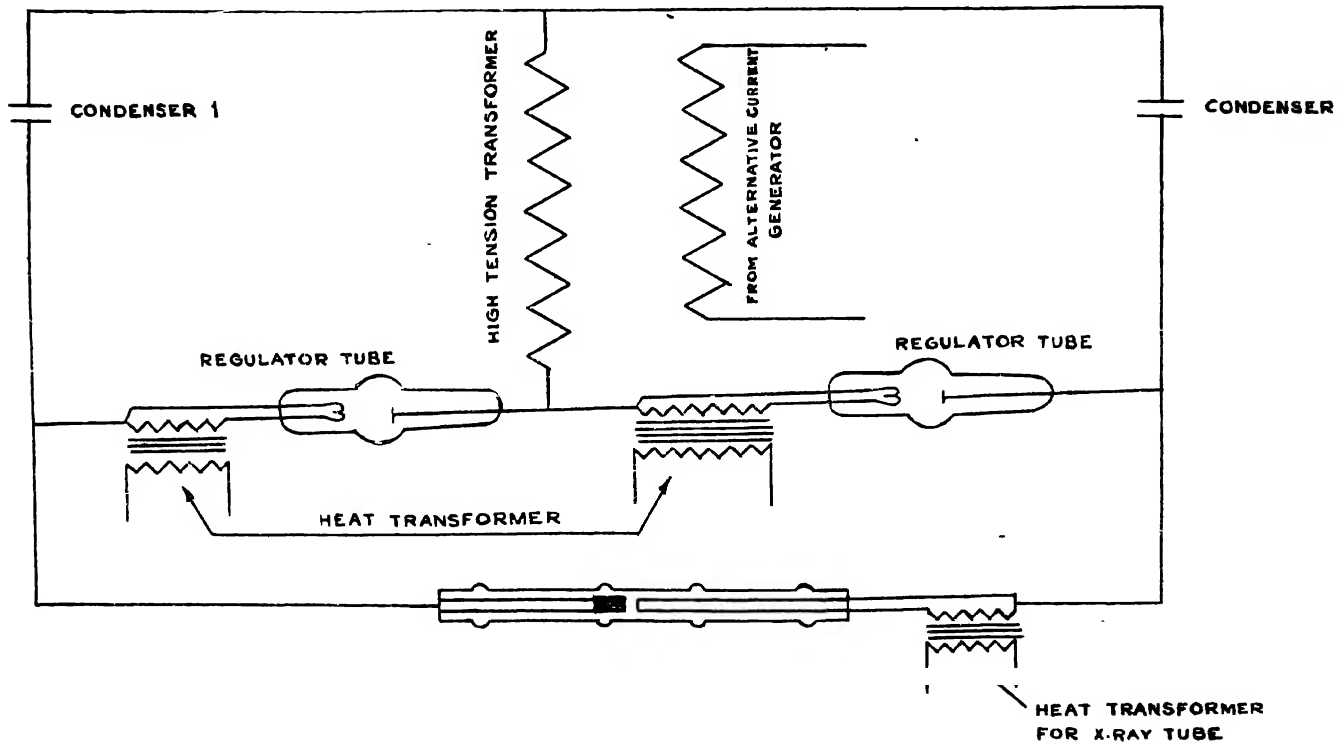
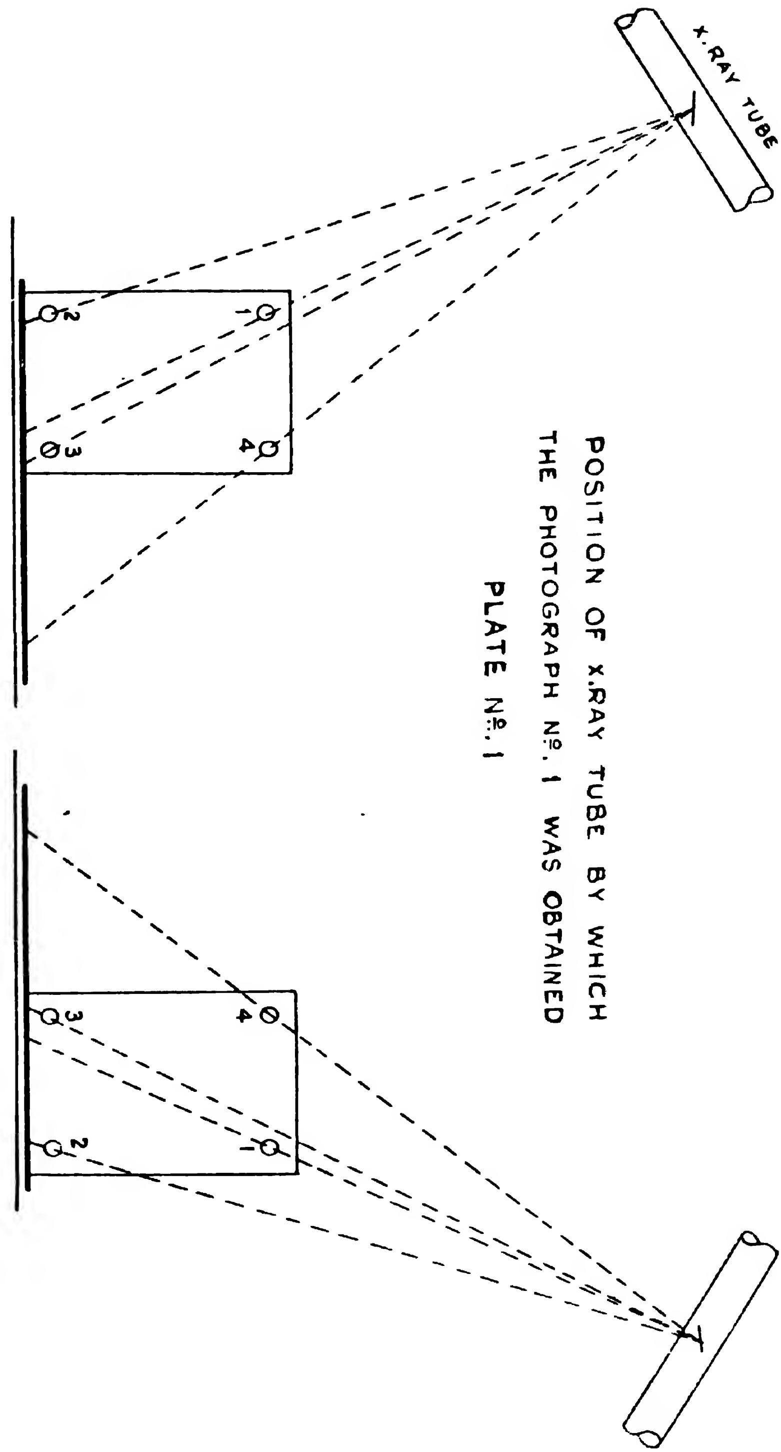


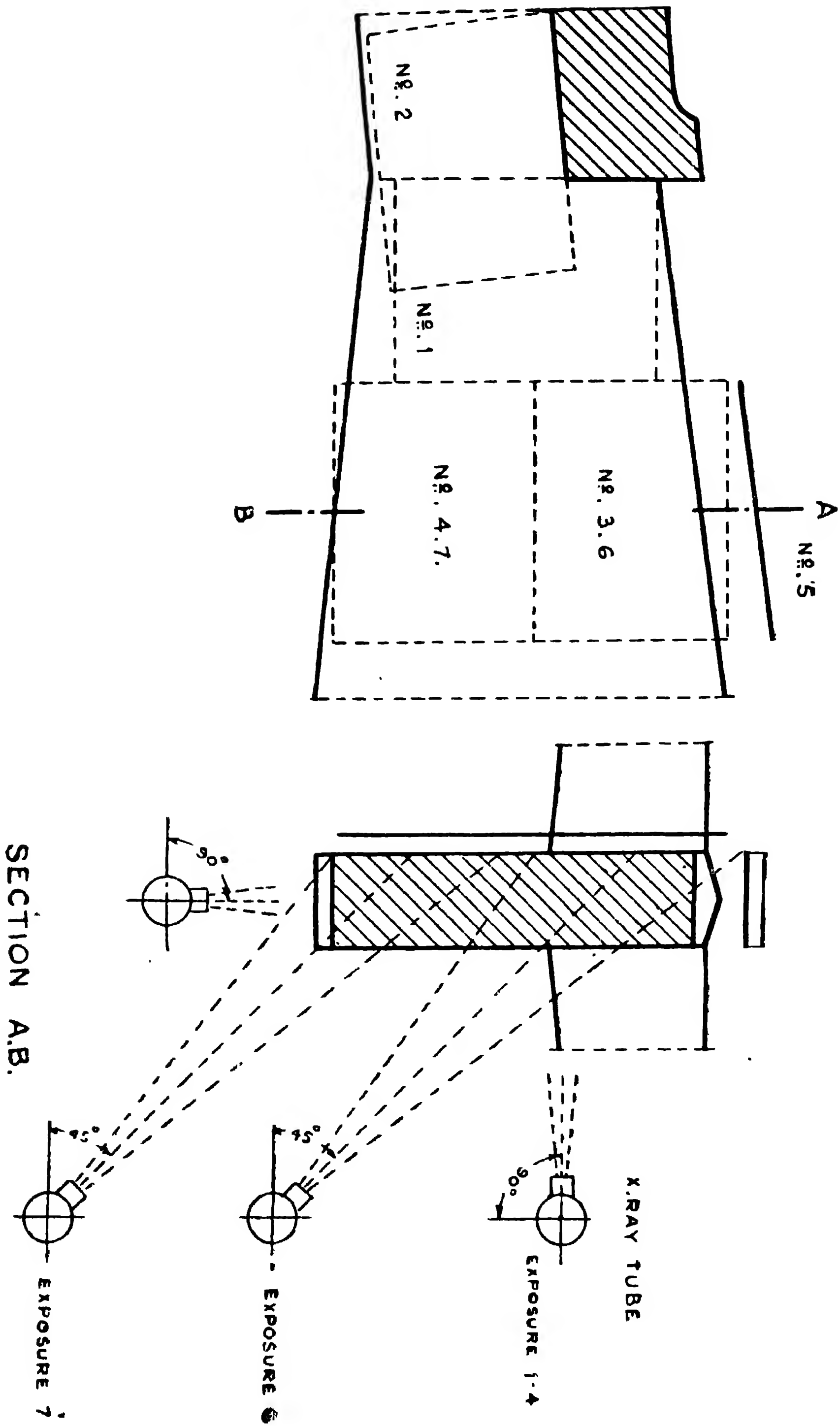
PLATE NO. 6

PLATE NO. 7

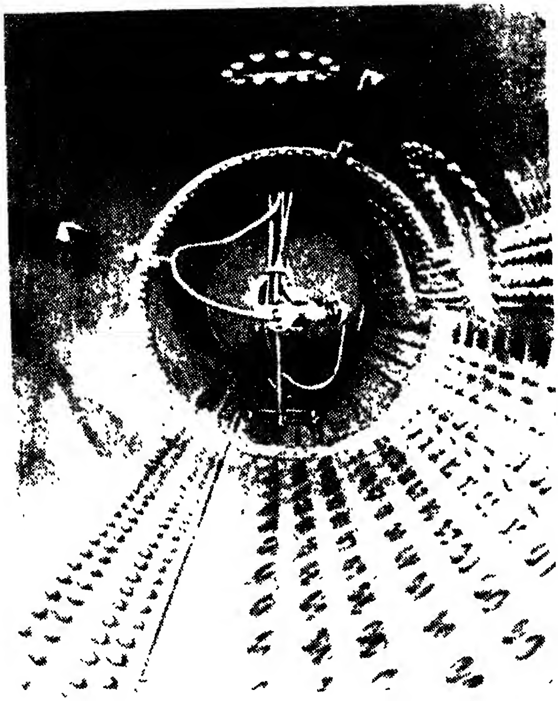


POSITION OF X.RAY TUBE BY WHICH
THE PHOTOGRAPH No. 1 WAS OBTAINED
PLATE No. 1

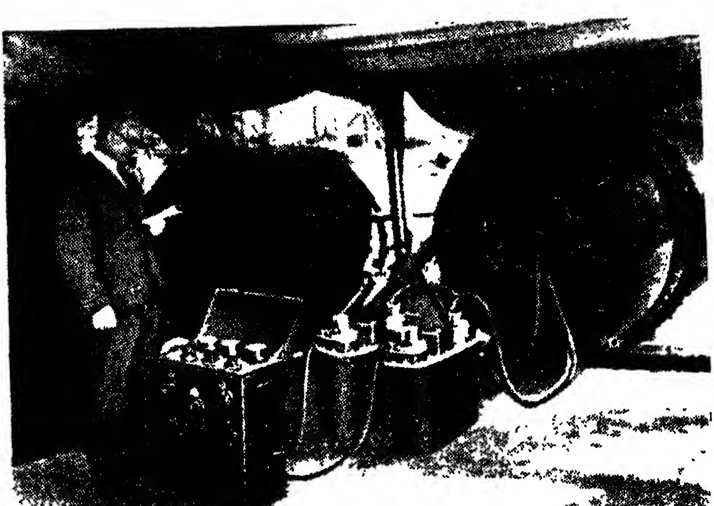
PLATE NO. 8



Nº. 2
Nº. 1
Nº. 4.7.
Nº. 3.6
Nº. 5
A
B
SECTION A.B.
90°
45°
45°
90°
X.RAY TUBE
EXPOSURE 1-4
EXPOSURE 6
EXPOSURE 7



Mounting of the Tube.



X-Ray examination of a Boiler Shell with the Ray Beam projected from the interior outwards.

PLATE NO. 10

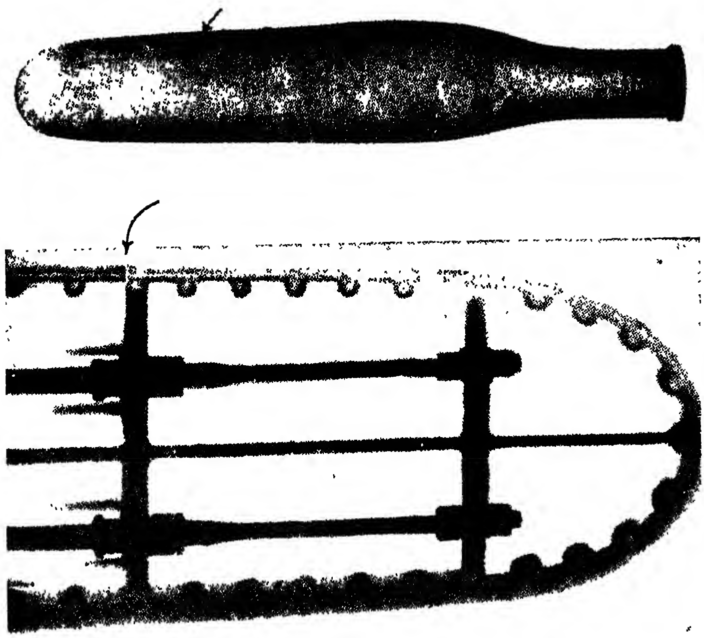
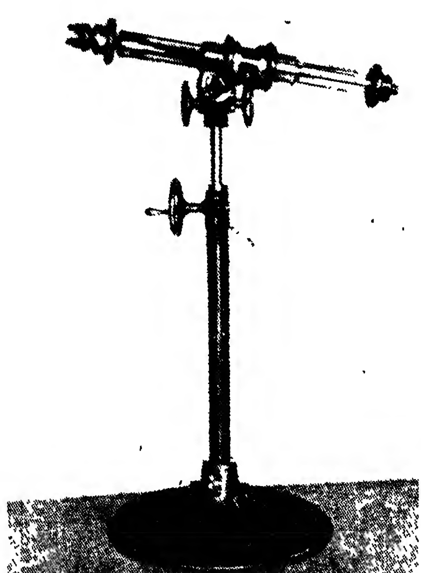


FIG. 4 Radiograph of propeller blade. The propeller is of light-metal with internal bracing. Notice flaw on the upper edge of the blade which is not visible to the naked eye.

FIG



X.RAY TUBE FIG. 2

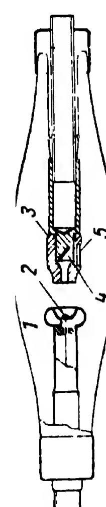


FIG. 4

FIG. 1

FIG. 2

FIG 3

FIG. 4

FIG. 5

X-RAY PHOTOGRAPH OF ELECTRO WELDED SEAM

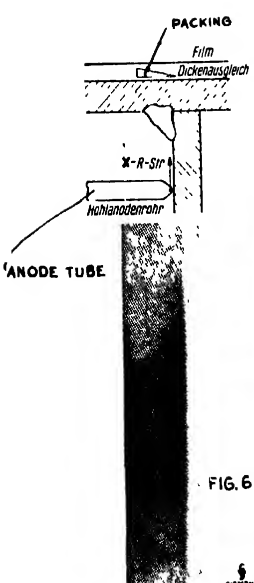


FIG. 6

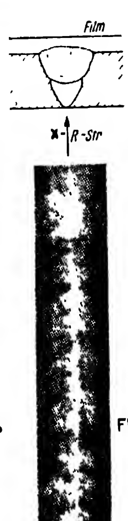


FIG. 7

FIG. 8

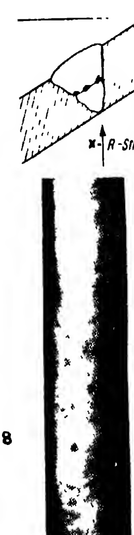


FIG. 9

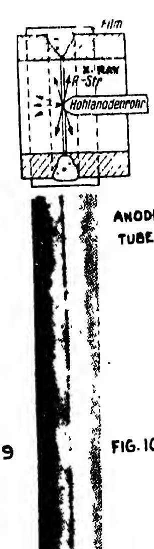
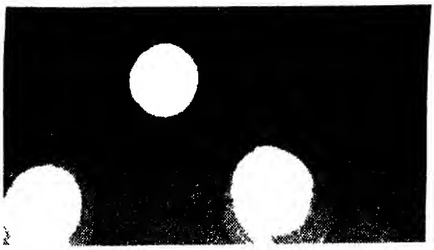


FIG. 10

PLATE NO. 12



X-Ray photo of a boiler, the rivet holes have signs of tearing.

Tearing of a boiler seam welded with Oxy-Hydrogen. The tearing is due to shrinkage. Could only be discovered by X-Ray.

FIG. 9. Alloy showing segregation of constituent metals.

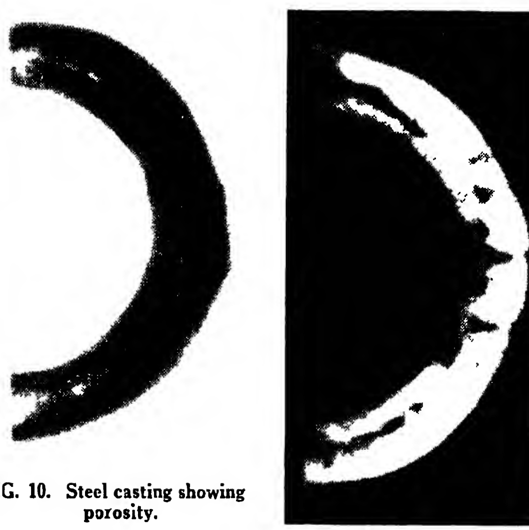


FIG. 10. Steel casting showing porosity.

PLATE NO. 13

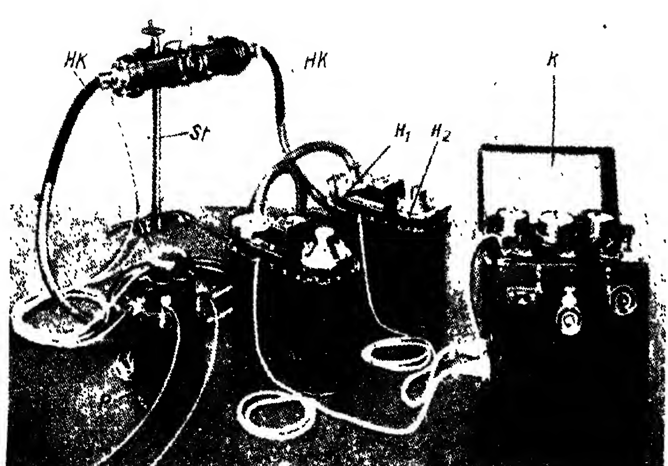


FIG 1. Transportable X-Ray Equipment. Power 200kV, 8 mA.

very keen on acquiring an X-ray outfit, but they dropped the idea ; it was a pity. Siemens & Halske in India have opened a department for technical X-ray equipments, and are willing to any plants for making X-raying possible. Their Indian X-ray office is represented by a highly specialised gentleman who will be only too glad to help in selecting the equipment and so is the author of this paper. Besides Siemens & Halske there is another firm "Philips" who have supplied technical offices on the Continent with excellent X-ray apparatus.

"ECONOMICS OF DECCAN CANALS—SELECTION OF WATER DEPTH."

BY

Rao Saheb N. S. JOSHI, B.E. (Bom.), M.I.E. (Ind.), M.R. San. I. (Lond.)

SUMMARY.

This paper is one of the series on the economic designs of Deccan Canals, the first one being "the Economic Bed-fall of Canals," published by the Bombay Engineering Congress and the second being read last year before the Institution of Engineers on "Lacey's Theory and Deccan Canals". The Author has shown that the configuration of the country and geological formation of Deccan has nothing common with the alluvial tracts of Upper India and that the silt theories there have no bearing on Deccan Canals. There is an amount of latitude in the velocity allowable in the canals as material cut through is hard and silt in canal waters is extremely small and collodial. Having fixed the surface slope as per his formula for "Economic Bed-fall of Canals," the waterway is determined and a suitable depth of water remains to be chosen.

The Author has shown that while a designer may select a very wide channel with small depth of water, or *vice versa*, two opposite factors came in. These were :

(1) The increase in the depth of cutting and height of bank as compared with the balanced section, the deviation from which is a function of the bed-width *i.e.* an inverse function of the water depth.

(2) The losses by percolation which increased with the depth of water under Deccan conditions.

These two factors working in opposite directions, give an optimum depth of water with which the cost of first construction plus the capitalized value of the losses by percolation give a minimum. The Author gives tables and graphs for this, from which the most economic depth of water to be chosen in any case can be found out.

Introductory.

One of the problems for the designer of irrigation Canals is the selection of a suitable depth of water for the design of his channel, the discharge and the bed-fall having been already determined by other considerations. This is the same as selecting the water depth, the waterway area having been determined. To take a concrete

example, suppose a channel requires a waterway of 200 sq. ft. It is possible to have a 2′ depth and 100′ width at one end and also a 16′ depth and 12·5′ width at the other. The problem for the designer is "which out of the whole lot should he choose." One possible reply may be that the shape which gives the maximum H. M. D. involves minimum excavation and is hence to be chosen. This argument cannot obviously apply to the Deccan, where hard rock is met with a few feet below the ground level. It must also be explained that silt theories applicable to alluvial tracts have no bearing on these canals. The points of difference have been detailed in other papers, written by the Author, but may be summarized here :—

(1) Hard rock is met with 1′ to 2′ below G. L. and costs about 10 times as much to excavate as the ordinary soil at surface.

(2) The soils are inerodible within limits ; even banks can be protected by murum casing and hence the range of permissible velocities is high.

(3) The silt carried in suspension by Canals is only about 10 to 20 parts per 100,000, *i.e.*, only about. 1/7 as much as that carried by Canals in alluvial tracts. Besides, the size of the silt particles is only about 0·008 millimeters (this being about 1/50th of that in the Punjab silt) and hence the silt cannot drop down. The major portion of silt in waters stored in reservoirs is deposited in the lakes and does not go to the Canals.

(4) Actual data for the Deccan Canals does not agree with any of the silt theories like those of Kennedy or of Lacey.

Hence formulae based on silt theories for alluvial tracts cannot be taken as a guide in solving the problem for the Bombay Deccan and allied tracts. It will, for example, be interesting to note that Lacey's theory requires certain ratios of

water-width to water depth for regime channels having velocities shown in the table below :—

Velocity.	Ratio $\frac{\text{Surface-width.}}{\text{Water-depth.}}$
0·88	2·0
1·00	3·6
1·50	7·1
2·00	10·1
2·50	13·1
3·00	16·0
4·00	21·8

We know, however, that a number of Canals in the Deccan having a velocity of the order of 1·8 ft./sec. have a surface width which is only 6 times as much as the water depth but have had no trouble. On the other hand the Nira Right Bank Canal has a velocity of less than 1·5 ft./sec. but the ratio of surface width to water depth is as large as 15 and even then there is no trouble. There is hardly any deposition of silt where there are no weeds, rotational running of canals having definitely put a stop to that pest.

In dealing with the problem under discussion, we have to be guided mainly by economy in the cost of first construction as well as by such indirect factors like losses in transit which under Deccan conditions depend upon the water depth. In the Deccan, the cost of maintenance of a channel having a given waterway does not depend upon the water depth to any considerable extent unless the design is almost absurd. But if, in the opinion of any, this has an effect, it is necessary to express it in terms of money, so as to allow due consideration being given to the same. It may for example be recorded that the amount required annually for silt removal in the Nira Left Bank Canal is only about Rs. 20/- per mile, while the cost of first construction ranges from Rs. 30,000 to 60,000. The capitalized value cf Rs. 20 forms a negligible part of the cost of original construction. With this introduction, we may now turn to the subject proper.

Alignment of Deccan Canals.

The country in the Bombay Deccan consists of rocks of igneous origin with a thin layer at surface disintegrated into murum and soil. The depth of this soft layer varies from nearly nothing on top of rocky ridges to about 4 feet. In valleys where the canal is in full bank generally, the depth of softer material is sometimes considerable (10 to 20′ or even more at times), the material being called chopan, man or conglomerate depending upon the amount of sand and shingle contained in the same. This strata met with locally in valleys only, is of aqueous formation. The canal alignment follows a falling contour, the slope of which has been predetermined. This falling contour goes round noses of ridges and corners of valleys (Please see fig. 1), the idea being to have a "balanced section" (excavation used up for embankment). Deviations from the falling contour are however unavoidable at certain points. Thus when crossing a valley the line has to go in full embankment to allow a cross drainage work to be constructed below the Canal bed level. It is sometimes possible to stick to the falling contour even here by providing a super-passage, but this cannot always be done. Similarly it is sometimes possible to avoid a detour round a ridge by having a direct cut, but such lengths are few.

In general, lengths of the Deccan Canals fall under one of the following 5 categories.

S. No.	Category.	Description.	Frequency of occurrence.
	Very deep cuttings.	Adopted with a view to avoiding a detour round a ridge. This direct alignment is rarely more economical in the cost of first construction, but is sometimes adopted on a consideration of saving in the losses in transit and also in the time taken by the waters to reach the tail. The depth of maximum cutting, is several times the depth of water for which the canal has been designed.	Rare. Hardly about 5% and in some cases upto 10% of the total length. The cost per unit length is excessive and in many cases prohibitive. Lining can help to reduce cost.

S. No.	Category.	Description.	Frequency of occurrence.
2	Ordinary full cuts (Please see Figs. 2 & 3, Section at "ZZ").	The radius for the Canal is fixed as a certain multiple (generally 20) of the width of the channel, while the natural curves of the ridges and hence of the falling contour are sharp. It is, therefore, impossible to avoid a deviation from the falling contour. Cuts with depths equal to about twice the water depth are usual in good designs.	Common. Total length under this category may be about 20 to 30% of the total length of the Canal.
3	Balanced Section (Please see Figs. 2 & 3, Section at "XX").	The falling contour is so fixed that the material excavated for the channel is all used for making the side banks. The depth of cutting is generally less than half the water depth.	Very common in good country. 40 to 70% of a Canal may have a section nearly agreeing with the balanced section except in rugged or side long tracts.
4	Ordinary full banks (Please see Figs. 2 & 3, Section at "YY").	Unavoidable for reasons similar to those explained under (2) the curves involved in this case being those of the falling contour in valleys. The height of bank below canal-bed-level is about one to two times the water depth in good designs.	Common. Total length 15 to 30% of the total length of the Canal.
5	Very high banks.	Adopted with a view to avoiding long detours up the valleys of large nallas or of rivers crossed by a canal. The advantages claimed are similar to those under (1). One of the main objections to very high banks is that if a breach occurs in such a length, the risk involved is enormous.	Very rare. 4 to 8% of the total length. Cost per running foot is very prohibitive.

—ECONOMICS OF DESIGNS OF CANALS—

— IN THE BOMBAY DECCAN AND OTHER ALLIED TRACTS —

— SELECTION OF WATER-DEPTH —

— BY —

RAOSAHEB N. S. JOSHI B.E., M.I.E., M.R. San. I.

— FIGURE No. 1 —

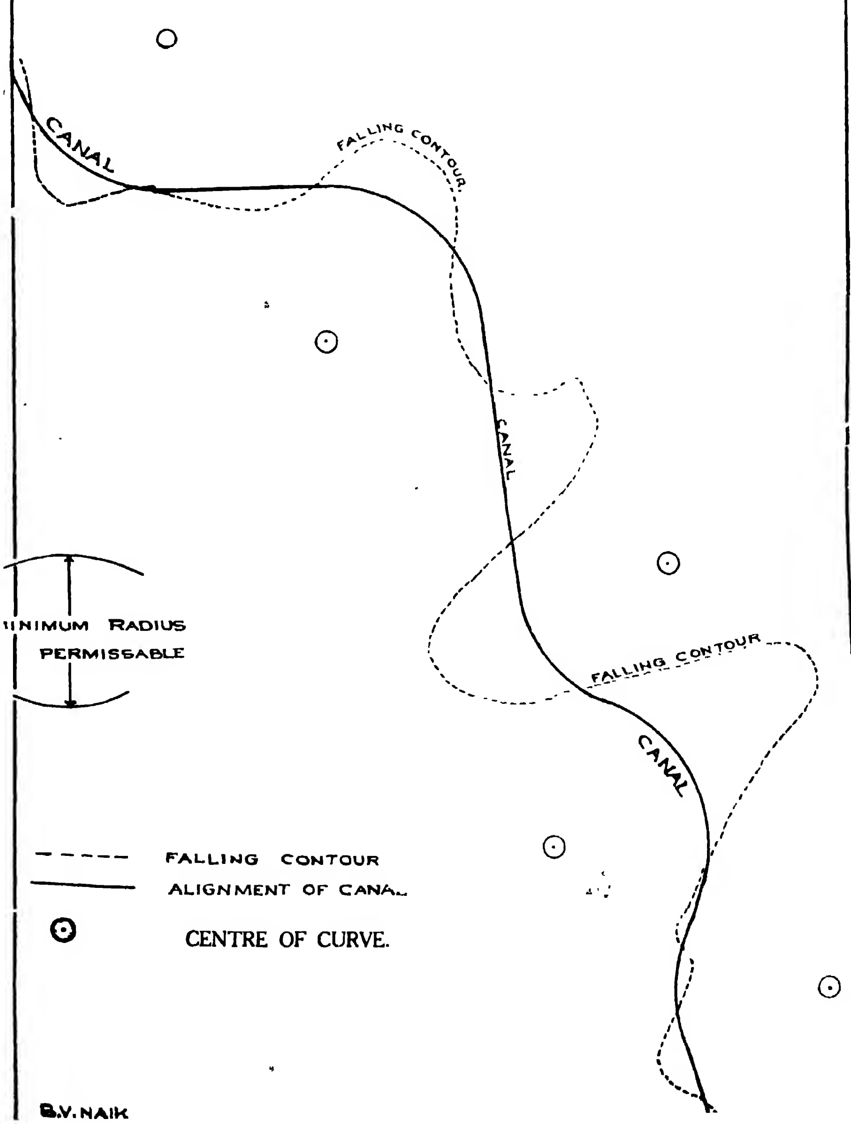


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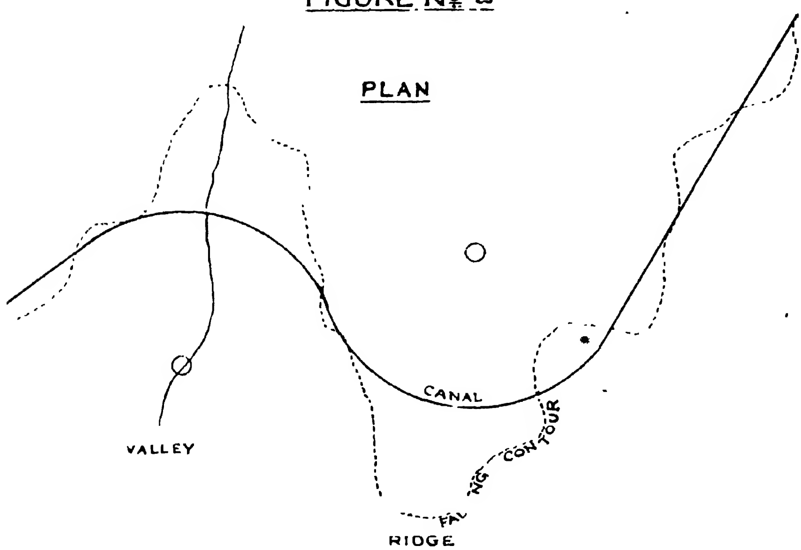
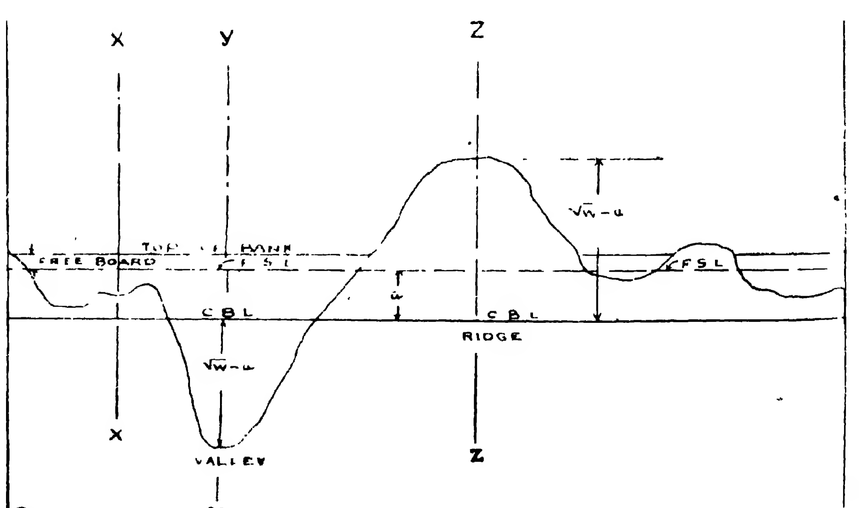
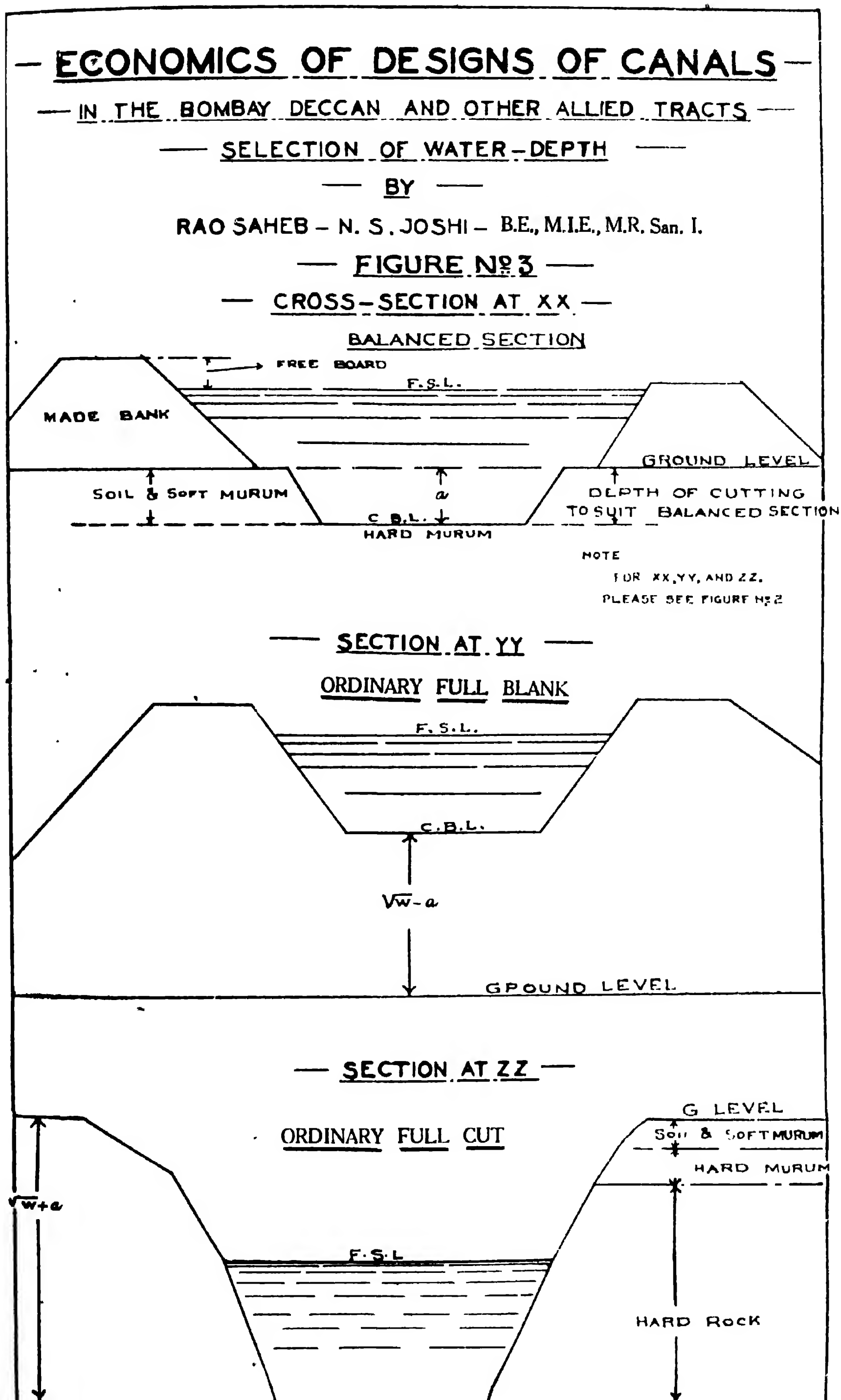
FIGURE No 2



LONGITUDINAL SECTION




ECONOMICS OF DESIGNS OF CANALS
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RAO SAHEB – N. S. JOSHI – B.E., M.I.E., M.R. San. I.
FIGURE No 3
CROSS-SECTION AT XX
BALANCED SECTION
FREE BOARD
F.S.L.
MADE BANK
GROUND LEVEL
SOIL & SOFT MURUM
a
DEPTH OF CUTTING
TO SUIT BALANCED SECTION
C.B.L.
HARD MURUM
NOTE
FOR XX, YY, AND ZZ,
PLEASE SEE FIGURE No 2
SECTION AT YY
ORDINARY FULL BLANK
F.S.L.
C.B.L.
√w - a
GROUND LEVEL
SECTION AT ZZ
ORDINARY FULL CUT
G LEVEL
SOIL & SOFT MURUM
HARD MURUM
√w + a
F.S.L
HARD ROCK

— ECONOMICS OF DESIGNS OF CANALS —

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— SELECTION OF WATER-DEPTH —

BY
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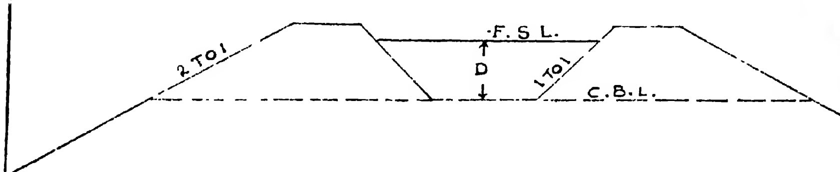
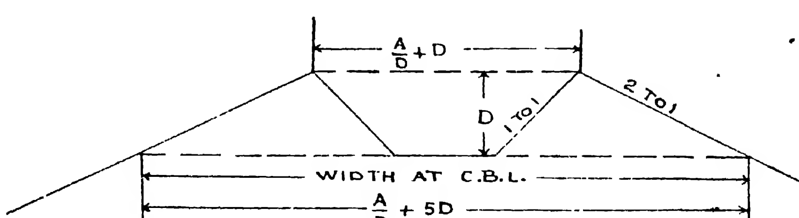
— FIGURE № 4 —

— TYPICAL SECTION IN EMBANKMENT —





NOTE

A = AREA OF WATER WAY (SQUARE FEET)

D = DEPTH OF WATER IN FEET

Of the 5 categories, the first has no direct bearing on the problem under consideration. The reason is obvious. A very deep cut is more an exception than a rule and therefore the selection of water-depth cannot be fixed with reference to that only. Considered from the point of view of very deep cuts alone, a very high depth of water would appear to be suitable as that would reduce the width of the cut to a minimum. This would, however, enormously increase the cost per unit length of the canal in portions falling under the other categories. Besides such a large water-depth would increase losses in transit to an extremely high figure. Actually a very deep cut is to be resorted to only under exceptional circumstances for reasons stated above. Hence the selection of water-depth has to be made on the considerations of the four remaining categories.

Considerations of very deep cuts.

Before dealing with the cases under categories 2, 3 and 4, we shall consider category No. 5. This category too is more an exception than a rule, but for the purposes of our investigation it goes hand in hand with category No. 4. Besides it serves to illustrate in very easy terms that there is an optimum depth, *i.e.*, one that allows the cost to be kept down to a minimum—the cost being larger whether the depth is greater or less than this optimum. This is explained below.

Considerations of very high banks.

Suppose we have to construct a Canal with a waterway area equal to "A" sq. ft. If we keep in view the fact that the quantity of earthwork in very high banks must be kept down to a minimum, we must try to have the width of embankment at C. B. L. a minimum. For, in the case of very high banks, the quantity of earthwork in side banks is only a small fraction of that below C. B. L.

Fig. 4 shows the cross section of such a bank.

As the top width of side banks and the free board are the same whatever the water-depth we may consider a section without these.

If we assume the inside slopes to be 1 to 1 and the outside slopes to be 2 to 1, the width at C. B. L. will be equal to $5D + \frac{A}{D}$,

Putting this in the form of an equation, we may write

$$y = 5D + \frac{A}{D}$$

where D is a variable.

Differentiating with respect to D and equating to zero we get—

$$\frac{dy}{dD} = 5 - \frac{A}{D^2} = 0$$

$$\frac{d^2y}{dD^2} = \frac{A}{D^3}$$ a + ve quantity as A and D are both + ve integers.

Then y is a minimum when $D = \sqrt{\frac{A}{5}}$.

In other words, if we choose a water-depth equal to $\sqrt{\frac{A}{5}}$ the width of full bank at C. B. L. and hence the quantity of earthwork in full bank below C. B. L. will be a minimum. This however, is not the final solution. Two other factors require consideration, (1) the H. M. D. which changes with the water-depth though the area is constant, and (2) losses by percolation which increase with an increase in the water-depth. It is shown in Appendix No. 1 that when all these factors are allowed for, we should keep

$$D = \frac{9}{10}\sqrt{\frac{A}{5}} \quad \ldots\ldots\ldots\ldots (1)$$

If we keep the side slopes inside the channel, at $1\frac{1}{2}$ to 1 instead of 1 to 1, the equation becomes

$$y = 5{\cdot}5\,D + \frac{A}{D}$$

and the solution of the equation for economic depth gives $D = \sqrt{\frac{A}{5{\cdot}5}}$ which, with due consideration for H. M. D. and losses, becomes $D = \frac{9}{10}\sqrt{\frac{A}{5{\cdot}5}}$ for reasons explained in Appendix No. 1.

What has been shown above to be true of full banks is also true of culverts on Nallas. The length of a culvert is the

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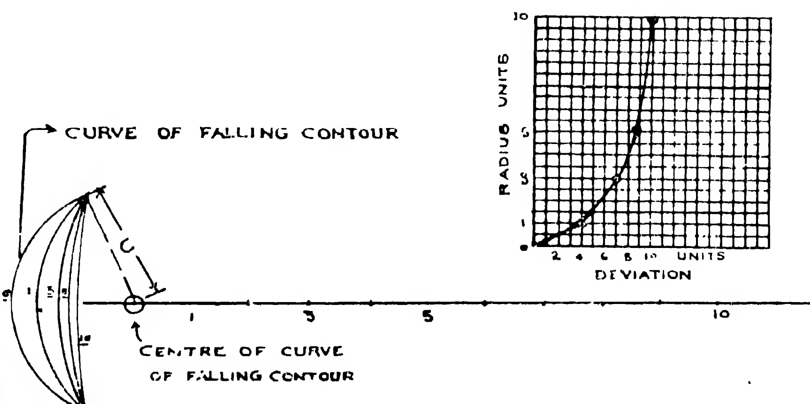
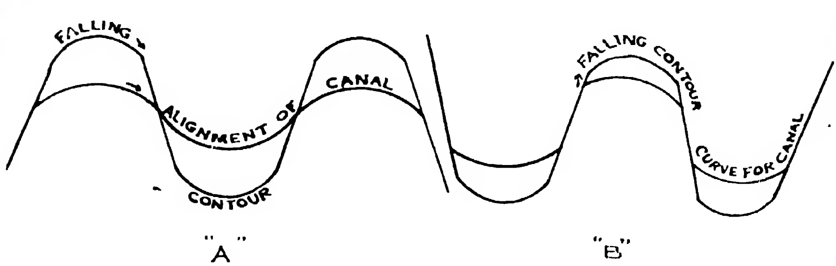
FIGURE No. 5



1, 3, 5, 10, ETC., ARE POINTS OF CENTRE OF CURVES CORRESPONDING OF CURVES MARKED AS 1, 3, 5, 10, ETC., which represent curves as per actual alignment of canal with centres at 1, 3, 5, 10 &c.



WHEN TWO ADJACENT CURVES ON A FALLING CONTOUR ARE TO BE ROUNDED OFF THE DEVIATION IS FURTHER INCREASED.

Compare cases A and B above.

(NOTE :- ACTUAL RADIUS IN BOTH CASES IS THE SAME.)

B.V. NAIK

same as the width of full bank at C. B. L. and it is obvious that the cost of the culvert varies directly as this width. The solution found above, therefore, holds good for economy in the construction of very high banks as well as of culverts on Canals. The same equation is true to a certain extent for moderately high banks also.

Same optimum depth for high banks and for culverts on Nallas.

It has been shown in the explanations against items 2, 3 and 4 in the statement above that while the radius of curvature of a natural falling contour is small, the radius for the curves of canal is large being kept by some equal to 20 times the bed-width. On this account a canal cannot follow the falling contour along all its length but has to deviate from the same at points where ridges and valleys have sharp corners. Due to the cross fall of ridges and valleys a canal has unavoidably to go in a deeper cut on ridges and in full bank in valleys at these points. A reference to Fig. 5 will show that the larger the radius the greater the deviation. As the radius is itself a function of the average bed-width of a canal, it is obvious that greater the bed-width larger the deviation. The rate of change of the deviation however gets lesser and lesser as the radius becomes very large. For general conditions obtained in the Deccan, it is found that the following thumb rule holds good.

Cases of full cuts, full banks and balanced sections. Unavoidable deviations, from the falling contours

$$d = \sqrt{W} \quad \ldots\ldots\ldots \quad (2)$$

Where d is the rise or fall vertically above or below the level of the falling contour and W is the average width of the canal. This will show that for a given water-way area the smaller the water-depth, larger the deviation from the falling contour and *vice versa*.

If we had to determine the water-depth on a consideration of the balanced section only, *i.e.*, without consideration for curves, a very small depth of water would be indicated, as that would avoid rock cutting as far as possible, and so chosen that material obtained from excavation is just sufficient for forming side banks. Consideration of economy in balanced sections alone would therefore require a large bed-width but this will involve considerable deviation from the falling contour at noses of ridges and at corners of valleys. A reference to graph "E" from

Paper No. 116 read by the Author before the Bombay Engineering Congress in 1928 will show that the cost per running foot of full cuts and full banks is several times that of a balanced section. A depth of water that may show the cost of a balanced section to be very small, is therefore not the most economic. A larger water-depth may increase the cost of the balanced section, but will reduce the amount of deviation from the falling contour and will on the whole give a much cheaper canal. The designed depth of water cannot however, be increased to an indefinite extent ; for, with a very large water-depth the cost of the balanced section itself is high ; but still more important is the fact that losses in transit increase with the water depth. A golden mean has therefore to be struck.

General lines on which the problem has been tackled.

It is not possible in this case to get a general equation to give a solution on the lines of equation No. 1 (page 208) which deals with the cases of very high banks and of culverts. The reason is that a number of factors have to be taken into consideration. The rates for excavation in rock increase with the depth of cutting. Similarly rates for earthwork increase with the height of banks as both lift and lead increase. Again rates for banks depend also upon the results of trial pit. Rates are high when the depth of soft material is small and *vice versa*. For these and similar other reasons it was necessary to work out rough estimates on standard lines for typical cases. In order to ensure uniformity, rates as shown in Appendix No. 2, were adopted in all estimates. This Appendix also gives tables for areas of embankments one for small and one for large canals. A table for deviations in height from the balanced section is also given.

Estimates in standard forms A, B and C—please see Appendix No. 4—have been worked out for each of the water-ways mentioned below.

20, 50, 100, 200, 500, 1,000 and 2,000 sq. ft.

Details of estimates.

A wide range of water-depths is considered. Thus in the case of 200 sq. ft. of water-way, costs have been worked out with water-depths from 2 feet to 10 feet, although both these extremes are obviously

impossible. The most economic and balanced section is first determined by estimating in Form A (please see Appendix No. 4) for every possible water-depth for a given water-way. Three different conditions are tried.

Optimum balanced section. Form "A".

(1) for country with 4′ soft material and rock below;

(2) for country with 2′ soft material and rock below; and

(3) for country with exposed rock.

The depth of partial cutting with which the cost of the balanced section is a minimum for a given water-depth and a given water-way area is thus determined for each of the types of material. Suppose this is represented by the symbol "a".

It has been shown above that the depth of cutting at the nose of the ridge is more than "a" by a depth equal to $\sqrt{W}$. In other words, the depth of cutting on ridges is equal to $(\sqrt{W} + a)$. Similarly the height of bank in valleys is equal to $(\sqrt{W} - a)$. Cost for this depth of cutting and height of bank per unit length is then worked out, in Form B (please see Appendix No. 4). In doing so it is assumed that the trial pit at the ridge is harder (half depth of soft material) than that on the sides of the ridge—a detail that agrees with practice. It is also assumed that the velocity in a full cut is kept somewhat higher (33%) than that in a balanced section or in full banks, another detail which agrees with practice. These changes are common to all alternatives tried.

Deviation section. Form "B".

We have next to work out an average cost per unit length for the total length consisting partly of balanced sections and partly of full cuts and full banks. It will be agreed that in average tracts the following is a fair assumption. A length of balanced section is followed by 1/2 length in full cut; this being in its turn followed by a full unit length of balanced section again followed by 1/2 unit length of full bank—the whole chain again repeating itself.

Suppose the cost per unit length of the balanced section is A units. Also suppose that the cost per unit length of corresponding full cut and full bank is C and B respectively. Then the average cost per chain for the conditions detailed above will be as shown below :—

	Length in units.	Cost per unit.	Total cost.
Balanced section	1	A	A
Full cut	$\frac{1}{2}$	C	C/2
Balanced section	1	A	A
Full bank	$\frac{1}{2}$	B	B/2
Cost of one link	3		$2A + \frac{B + C}{2}$

$$\text{Average cost per unit length} = \tfrac{2}{3} A + \frac{B + C}{6}$$

The proportion of length in balanced sections and full cuts and banks will not be the same in a bad country. The percentage of length in balanced sections will be smaller while that of deviated sections will increase. On the other hand if the tract is very good, the changes in percentage lengths will be exactly opposite.

Five possible alternative conditions have, therefore, been considered.

Average cost per unit length for whole length: Form "C".

These are (1) hilly, (2) bad, (3) average, (4) good and (5) flat. The ratio of lengths of balanced sections and of full cuts and banks and also the average cost per unit length in each case are given below, the latter being in terms of costs of unit lengths in balanced sections, full cuts and full banks respectively being equal to A, B & C.

	Balanced Section.	Full Cut.	Balanced Section.	Full Bank.	Average cost per unit length.
Hilly ..	Nil	1	Nil	1	$\frac{B + C}{2}$
Bad ..	1	1	1	1	$\frac{A}{2} + \frac{B + C}{4}$
Average ..	1	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{2}{3} A + \frac{B + C}{6}$
Good ..	1	$\frac{1}{3}$	1	$\frac{1}{3}$	$\frac{3}{4} A + \frac{B + C}{8}$
Flat ..	1	Nil	1	Nil	A

These have been worked out on Form C. (Please see Appendix No. 4). Thus Form C gives the cost of first construction for each one of the five types of tracts and for each of the three types of trial pits.

As the area of water-way has been assumed to be constant while the depth of water is assumed to vary, the H. M. D. will not be the same and the discharging capacities will therefore not be the same in all cases.

Manning's equation is—

$$Q = \frac{1 \cdot 3458}{N} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

If therefore the area of water-way is the same, the discharge will be a function of $R^{\frac{2}{3}}$. A is correction therefore applied so as to make figures with different water-depths comparable. These corrected figures will then give a real comparison of the cost of first construction for a canal with the some discharging capacity but with different depths of water.

Consideration for H. M. D and hence for discharging capacity.

Consideration for the capitalised value of losses in transit.

One must not however be guided by the cost of first construction only. It is well-known that the losses in transit increase with the depth of water and for a real comparison this must be allowed for. The capitalised cost of losses in transit for channels with different depths have been worked out in accordance with the formulae proved by the Author in his paper on "Losses in transit through Deccan Canals." Paper No. 180, Bombay Engineering Congress, Vol. 27. Tables for these are given in Appendix No. 3, along with an explanatory note. The capitalised value of a fixed proportion of these losses is then added to the cost of first construction, worked out as explained above. The total cost per unit for different water-depths can then be compared with each other. What we have to find out is the depth for which this total is a minimum. It is obvious that losses in a perennial Canal occur throughout the year and that the value of water in hot weather is high. In a non-perennial canal, the losses occur only for 8 months and water is not so costly. Lastly, the period over which losses occur in a monsoon canal is very small and value of water is very low. It is obvious therefore that although the rate of losses per mile in a channel having the same depth may be the same, the capitalised value depends upon whether the canal is perennial, two seasonal or purely monsoon.

Estimates in Form. C give figures for each of these 3 types of Canals. We thus get an independent figure of ultimate cost per unit length for different water-depths for each of the 3 trial pits, each of the 3 types of Canals (perennial, two seasonal and monsoon) for each of the 5 types of tracts, considered above. It will, however, be noted that no (falling contour) canal in Deccan can fall under the first (*i.e.*, "Hilly") or the last ("Flat") category throughout its length.

This leaves 27 cases for each water-way area. The costs per 100 R. ft. as worked out by the standard estimates are plotted on a graph paper in three groups, *viz.*, (1) for bad country, (2) for average country, and (3) for good country. (Please see Appendix No. 5). Each group has 9 graphs, the "x" axis showing the depth of water and the "y" axis the cost per chain. An index is given above the graphs to allow any particular curve to be located easily.

Economic depth for the designs of contour channels for the main canal.

It will be seen that the curves are of the nature of a parabola, the apex points indicating the optimum depth of water, the ultimate cost involved being the minimum there. It is obvious that a channel should be constructed with this depth of water, if economy is to be aimed at.

The horns of the parabola are not symmetrical; that on the left hand side, *i.e.*, with the smaller water-depth has a steep rise indicating that reduction in the depth of water below the optimum is definitely dangerous. The right side horn has a comparatively flatter rise, so that an error on that side is permissible within limits.

On each of the groups of the 9 curves are also plotted curves for the cost of only the first construction. It will be noted that although the ultimate cost for a perennial, a non-perennial or a monsoon canal may be different, the cost of first construction for a given water-way area and with a given water-depth is the same for the same trial pit. The curves for the cost of first construction are, therefore, only three for each group, one each for soft, medium and hard materials. These curves are also parabolic and have points at which the cost of first construction will be a minimum.

It will be seen that the minimum points on the curves for the costs of first construction, are in all cases (except a few for 2,000 sq. ft.) towards the right-hand side of the minimum points on the graphs for ultimate cost (*i.e.*, the cost of first construction plus the capitalised value of the losses in transit), thus indicating that the depth of water should if at all, be greater than the optimum indicated by the curves of ultimate costs.

The importance of the cost of first construction cannot be too strongly impressed on the minds of the Engineers in the Bombay Deccan. The canals in this zone give a poor return, *i.e.*, such as is not sufficient to cover the amount of interest to be paid annually on the capital invested. The interest on the cost of a canal during the period of construction is really a part and parcel of the cost of first construction, and must also be taken into account. It is, therefore, very desirable to keep down the figure of the cost of first construction as far as possible even at the risk of allowing the ultimate cost to be increased slightly say by about 5 to 10% if necessary.

To allow the figure of optimum depths to be seen at a glance, they have been tabulated in a statement *vide* Appendix No. 5.

The optimum depths for any condition indicated by graphs for ultimate costs are really the minimum depths, while the optimum depths indicated by the cost of first construction are the maximum. The actual depth to be adopted in any particular case will be in between these two, the selection being made after considering the points explained above in detail, *i.e.*, after a careful study of the figures on the graph. The depths shown at the end of Appendix No. 1, may be compared with these.

Economic depth of water for designs of Distributaries.

The case of designs of Distributaries is very similar to that of the designs of the main canal, with the difference that the cost of a cusec of water in Distributaries is more than that in the main canal. In the case of lengths of Distributaries running along the falling contour—(a condition usually met with in the head reaches of important Distributaries of Deccan Canals). This is counterbalanced by the fact that the number of days for which the Distributary runs is only about half and in some cases 2/3 of those on which the main canal itself works. The case of falling contour lengths of a Distributary is hence similar to that of the main canal itself under similar conditions. The tail portion of large Distributaries however runs on the main ridge, *i.e.*, with the country sloping on either side. The importance of losses in transit in these portions is therefore great in spite of the number of days for which the Distributary runs being only one half. The depth of water in these lengths cannot, however, be based on the considerations detailed in the main paper in as much as the channel in these lengths is (in a large number of cases) in deep chopan-black soils, which are known to be impervious. For all practical purposes, therefore, the depth in these lengths too have to be kept the same as that in contour channels for a similar area, of water-way, the cost of first construction being very small.

General conclusions.

In conclusion, it is pointed out that there are certain considerations based on economy on which the design of sections of Canals, *viz.*, the water-depth and the width-to-depth ratio is dependent. Any change in this means waste of money. It is true that the estimates,

tables and graphs accompanying this paper are based on certain assumptions regarding the

(1) relation between the vertical deviation and the bed width of the channel.

(2) relation between the losses in transit and the depth of water in channel.

(3) the rates prevalent at present in the Bombay Deccan.

It is possible that these rates may change and also possible that the relation between deviations and width is different from that based by the Author from his observations. Lastly some may not agree with the relation between the losses and the water-depth in a given channel as adopted by the Author. It is true that change in these basic assumptions will affect our figures for the most economic water-depth for any given water-way area. The point of importance to be borne in mind however, is that even with these changes, the cost of first construction plus that of losses in transit is not the same for all water-depths and that a particular water-depth gives a minimum cost depending upon the factors explained. Any other water-depth will mean money not properly utilised. The main conclusion, therefore, still remains unchanged, though actual depth adopted may change *to some extent.*

To add to the assumptions mentioned above, we find that certain designers believe that the maintenance of the channel is a minimum if it has a particular width-to-depth ratio. In such cases the correct method for determining the optimum water-depth would be to include the capitalised value of maintenance charges for each of the alternatives to the cost of first construction and the capitalised value of losses in transit. That water-depth for which the total of these three is a minimum is obviously the minimum depth to be chosen, the maximum being that indicated by the graphs for the cost of first construction. The particular depth to be ultimately adopted will be in between these and will be selected on considerations discussed at length above.

APPENDIX No. 1

Economics of Designs of Canals in the Bombay-Deccan and other Allied Tracts.

Selection of Water-Depth.

It has been shown in the body of the paper, that if the area of water-way were equal to "A" sq. feet, and the water side and outside slopes of earth work were 1 to 1 and 2 to 1 respectively, then the width of bank at C.B.L. will be a minimum when the water-depth is equal to $\sqrt{\frac{A}{5}}$ (please see fig. 4). This solution however, neglects the fact that the discharging capacity is a function not only of the area of water-way but also that of the Hydraulic Mean Depth. Thus although the area may remain unchanged, the Hydraulic Mean Depth increases with an increase in water-depth till it reaches a shape such that

$$D = 1{\cdot}64 \sqrt{\frac{A}{5}}\ .$$

Hence although $D = \sqrt{\frac{A}{5}}$ represents a condition when the width at C.B.L. is a minimum, with "Area" as a non-variable it does not do so when we have to compare the discharging capacity of the channel. The accompanying table has therefore been prepared to find out a condition when the width of earthwork at C.B.L. is a minimum with the same discharging capacity of the channel in question, as that of the standard channel with $D = \sqrt{\frac{A}{5}}$.

It will be seen from this table that the minimum width at C.B.L. is obtained when

$$D = 1{\cdot}10 \sqrt{\frac{A}{5}}\,.$$

When this condition obtains, the earthwork below C.B.L. is a minimum. Actually, however, there is some quantity of earthwork in side banks also and this quantity increases with the water-depth. It is not possible to lay down the relation between increase in the quantity of side-bank and the decrease in the portion below C.B.L. in the form of a general equation to be differentiated and solved for a minimum. However, it is sufficient to note, *e.g.*, that with a height of full bank, (below C.B.L.) equal to the designed depth of water, the quantity in side banks is 50% of that below C.B.L. but falls down to only about 10% if the height of full bank is twice as much as the water-depth.

Two other factors have also a bearing on determining the most economic water-depth. These are—

(1) The losses by percolation and

(2) Chances of breaches in canal banks.

Neither of these factors can be stated in mathematical terms. So far as the losses by percolation in the embankment section by itself are concerned, our knowledge is limited. It is not definitely known whether it is a function of the water-depth (as in the case of Muram cuttings) or the wetted perimeter (which reduces with the water-depth till $D = 1{\cdot}64 \sqrt{\frac{A}{5}}$).

The depth of water in embankment sections has however to be the same as that in the rest of the canal. Further losses by percolations through banks form only a small portion of those through Muram cuttings.

Reduction in the water-depth has therefore certain important advantages.

Lastly the chances of breaches increase with an increase in the water-depth. The general dislocation caused by a single breach, the high rates that have to be paid for remaking the breached portions and the fact that costly crops covering thousands of acres are at stake, would also indicate against an increase in the depth.

APPENDIX No. 1

depths as compared with a standard channel (the in H.M.D. on the final width of full embankment at r-depth variable).

ırd channel with $D = \sqrt{\frac{A}{5}}$ where A = area of water-way.

).	D. Standard.	0·90 D.	0 75 D.	0 67 D.	0·50 D.	
	7	8	9	10	11	×
$\frac{A}{D}$	$\frac{A}{D}$	$1{\cdot}11\,\frac{A}{D}$	$1{\cdot}33\,\frac{A}{D}$	$1{\cdot}5\,\frac{A}{D}$	$2\,\frac{A}{D}$	×
$\frac{A}{D}$ D	$\frac{A}{D}-D$ ..	$1{\cdot}11\,\frac{A}{D}$ $-0{\cdot}90\,D$	$1{\cdot}33\,\frac{A}{D}$ $-0{\cdot}75\,D$	$1{\cdot}5\,\frac{A}{D}$ $-0{\cdot}67\,D$	$\left.\begin{matrix}2\,\frac{A}{D}\\ -0{\cdot}5\,D\end{matrix}\right\}$	
D	4 D	4·65 D	5 9 D	6·84 D	9·5 D	
D	2·86 D	2·57 D	2·15 D	1·91 D	1·43 D	
D	6·86 D	7·22 D	8·05 D	8·75 D	10·83 D	
D	0·73 D	0·69 D	0·62 D	0·57 D	0·46 D	
$D^{\frac{2}{3}}$	$0{\cdot}810D^{\frac{2}{3}}$	$0{\cdot}780D^{\frac{2}{3}}$	$0{\cdot}727D^{\frac{2}{3}}$	$0{\cdot}688D^{\frac{2}{3}}$	$0{\cdot}596D^{\frac{2}{3}}$	
	1·000	0·963	0·898	0·850	0·736	
D	6 D	6·45 D	7·4 D	8·16 D	10·5 D	
D	4 D	3·60 D	3 D	2·67 D	2 D	

Unfortunately it is not easy or possible to weigh the importance of each of these factors by the true balance of mathematical equations. It will, however, be seen that the reduction in the width of bank at C.B.L. achieved by increasing the water-depth from $\sqrt{\frac{A}{5}}$ to $1{\cdot}10\sqrt{\frac{A}{5}}$ is only about 2%. It will also be seen that the increase in the width at C.B.L. as a result of reducing the water-depth to $0{\cdot}90\sqrt{\frac{A}{5}}$ is only 3% as compared with the standard and 5% as compared with the optimum. The advantages in favour of keeping the water-depth at $0{\cdot}90\sqrt{\frac{A}{5}}$ can therefore be said to out-weigh those to be gained by a simple reduction in the width at C.B.L. The increase in the width at C.B.L. with a further reduction in the water-depth is large and the rate of change is rapid. Hence reduction in water-depth below $0{\cdot}75\sqrt{\frac{A}{D}}$ cannot be recommended except in the case of very large channels, *i.e.*, those requiring very large depths of water. The following results are therefore tabulated.

Area of water-way.	$D = \sqrt{\frac{A}{5}}$	$D = 0{\cdot}90\sqrt{\frac{A}{5}}$	$D = \frac{3}{4}\sqrt{\frac{A}{5}}$
10	1·4	1·3	
20	2·0	1·8	
50	3·15	2·8	
100	4·5	4·0	
200	6·4	5·8	
500	10·0	9·0	
1000	14·0	13·6	10·5
2000	20·0	18·0	15·0

These may please be compared with the depths indicated by the graphs, and the table printed in appendix No. 5.

APPENDIX No. 2.

Economics of Designs of Canals in the Bombay-Deccan and other Allied Tracts.

Selection of Water-Depth.

RATES ADOPTED IN ESTIMATES.

(1) Excavation.

		Rs.	Unit.
Soft material, including soil, murum, chopan etc. ..		$\frac{3}{4}$	100 c.ft.
	Depth below ground level.		
Rock	0— 5	4	,,
,,	0—10	$4\frac{1}{2}$	,,
,,	0—15	5	,,
,,	0—20	$5\frac{1}{2}$	,,
,,	0—25	6	,,
,,	0—30	$6\frac{1}{2}$	,,
,,	0—35	7	,,

(2) Embankment.

Partial Banks. Do.

Height of Partial Banks.	Nature of Trial Pit.		
	Soft.	Medium.	Hard.
0— 5	$\frac{3}{4}$	$\frac{3}{4}$	1
5—10	$\frac{3}{4}$	1	$1\frac{1}{4}$
10—15	1	$1\frac{1}{4}$	$1\frac{1}{2}$
15—20	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$
20—25	$1\frac{1}{2}$	$1\frac{3}{4}$	2

Embankments.

Rate per 100 c.ft.

Height of full Bank.	Nature of trial pit.	Depth of water.				
		0—5	5—10	10—15	15—20	20—25
Nil, *i.e.* partial banks nearly full	Soft	¾	¾	1	1¼	1½
	Medium	¾	1	1¼	1½	1¾
	Hard	1	1¼	1½	1¾	2
0—5	Soft	¾	1	1¼	1½	1¾
	Medium	1	1¼	1½	1¾	2
	Hard	1¼	1½	1¾	2	2¼
5—10	Soft	1	1¼	1½	1¾	2
	Medium	1¼	1½	1¾	2	2¼
	Hard	1½	1¾	2	2¼	2½
10—15	Soft	1¼	1½	1¾	2	2¼
	Medium	1½	1¾	2	2¼	2½
	Hard	1¾	2	2¼	2½	2¾
15—20	Soft	1½	1¾	2	2¼	2½
	Medium	1¾	2	2¼	2½	2¾
	Hard	2	2¼	2½	2¾	3
20—25	Soft	1¾	2	2¼	2½	2¾
	Medium	2	2¼	2½	2¾	3
	Hard	2¼	2½	2¾	3	3¼
25—30	Soft	2	2¼	2½	2¾	3
	Medium	2¼	2½	2¾	3	3¼
	Hard	2½	2¾	3	3¼	3½
30—35	Soft	2¼	2½	2¾	3	3¼
	Medium	2½	2¾	3	3¼	3½
	Hard	2¾	3	3¼	3½	3¾
35—40	Soft	2½	2¾	3	3¼	3½
	Medium	2¾	3	3¼	3½	3¾
	Hard	3	3¼	3½	3¾	4

Table showing increase or decrease in embankments and cutting from depth of balanced sections for known bed widths.

Vertical Deviation $= \sqrt{w}$

Bed width.	Deviation.	Bed width.	Deviation.
1	1	66—69	8·25
2	1·50	70—74	8·5
3	1·75	75—78	8·75
4	2	79—83	9
5	2·25	84—87	9·25
6	2·4	88—92	9·5
7—8	2·75	93—97	9·75
9	3	98—100	10
10—11	3·25	100—107	10
12—13	3·5	107—116	10·5
14—15	3·75	117—126	11
16	4	127—137	11·5
17—18	4·25	138—150	12
19	4·5	151—162	12·5
20	4·5	163—175	13
21	4·5	176—188	13·5
22—23	4·75	189—203	14
24—26	5	204—217	14·5
27—28	5·25	218—232	15
29—31	5·5	233—247	15·5
32—34	5·75	248—264	16
35—37	6	265—280	16·5
38—40	6·25	281—297	17
41—43	6·5	298—314	17·5
44—46	6·75	315—332	18
47—50	7	333—350	18·5
51—53	7·25	351—370	19
54—58	7·5	371—389	19·5
59—61	7·75	390—410	20
62—65	8		

Area table for side banks and width at C. B. L. for working out areas of full banks, for larger canals with areas of water-way larger than 100 sq. ft.

	Top width.	Side slope.	Free board.
Bank on upstream	4	$1\frac{1}{2}$ to 1	2
Bank on downstream	12	$1\frac{1}{2}$ to 1	2

Height of bank (not including free board) *i.e.*, water-depth.	Area of side banks both.	Width of side banks at C. B. L.	Width for working out areas of full banks, *average* B. W. to be added.	Height of bank (not including free board) *i.e.*, water-depth.	Area of side banks.	Width of side banks at C. B. L.	Width for working out areas of full banks, *average* width of canal to be added.
..	0	16	..	14	1024	112	91
..	19	22	..	15	1139	118	96
0	44	28	28	16	1260	124	100
1	75	34	33	17	1387	130	104
2	112	40	37	18	1520	136	109
3	156	46	42	19	1659	142	114
4	204	52	46	20	1804	148	118
5	259	58	50	21	1955	154	123
6	320	64	55	22	2112	160	127
7	387	70	60	23	2275	166	132
8	460	76	64	24	2444	172	136
9	539	82	68	25	2619	178	141
10	624	88	73	26	2800	184	145
11	715	94	78	27	2987	190	150
12	812	100	82	28	3180	196	154
13	915	106	86	29	3379	202	159
				30	3584	208	163

Area table for side banks and width of bank at C. B. L. for working out areas of full bank for small canals with areas of water-way less than 100 sq. ft.

	Top width.	Side slope.	Free board.
Both banks.	4′	$1\frac{1}{2}$ to 1	2′

Height of bank (not including free board) *i.e.* water-depth.	Area of side banks *both*.	Width of side banks at C.B.L.	Width for working out areas of full banks, *average* width of Canal to be added.
..	0	..	..
..	11	14	..
0	28	20	20
1	51	26	25
2	80	32	29
3	115	38	34
4	156	44	38
5	203	50	43
6	256	56	47
7	315	62	52
8	380	68	56
9	451	74	61
10	528	80	65

APPENDIX No. 3.

Economics of Designs of Canals in the Bombay-Deccan and other Allied Tracts.

SELECTION OF WATER-DEPTH.

Capitalized value of losses in transit in Irrigation Canals in Bombay-Deccan.

For working these out, canals will have to be divided into 3 varieties :—

(1) Perennial, *i.e.*, flowing all the year round.

(2) Non-perennial, *i.e.*, flowing from June to February but not in the hot weather.

(3) Monsoon, *i.e.*, flowing from June to September, *i.e.*, when rivers are in floods.

The capitalized value of a cusec depends upon the revenue fetched by a cusec in the period during which it flows. The following figures have been assumed as they agree with those met in actual practice.

—	Type of crop with respect to season.		
	Perennial (cane).	Two Seasonal. (rabi & kharif)	Monsoon.
Duties at canal head ..	30	80	120
Rate per acre ..	45	8	3
Value of a cusec season ..	1350	640	360
Value of a cusec season after allowing for partly free monsoon flow ..	1200	500	250

Duties at distributary heads are higher and therefore capitalized cost there is much higher. Generally speaking duties at distributary heads and values of cusecs are as under :—

—	Type of crop with respect to season, etc.		
	Perennial.	Two Seasonal.	Monsoon.
Duties at distributary head	45	120	180
Rate per acre ..	45	8	3
Value of a cusec season ..	2025	960	540
Value of a cusec season after allowing for partly free monsoon flow ..	1800	750	375

Note.—The above two tables are based on data available for the larger canals in the Bombay-Deccan. In the case of the smaller canals they are generally non-perennial or monsoon.

The value of a cusec-year, for the purpose of working out losses in transit, is therefore high in the case of a perennial, much smaller for a non-perennial and very small for a monsoon canal. In other words, it may be a sound proposition to spend a large amount with a view to reducing the losses by percolation through a perennial canal but this will not be justifiable in the case of a non-perennial canal.

It has been shown in paper No. 180, Bombay Engineering Congress, that for every Mile of a canal,

Losses $= 0{\cdot}50 + D/5$ in a contour channel, and

Losses $= 0{\cdot}60 + D/2{\cdot}5$ in a ridge channel.

It should, therefore, be possible to work out losses for various depths of water and to capitalize their value for the 3 types mentioned above. If the capitalized value of a cusec is worked out at 5% the figures will be as under :—

Perennial Canal ..	.. 24,000
Non-Perennial Canal	.. 10,000
Monsoon Canal ..	.. 5,000

Perennial Distributary	.. 36,000
Non-Perennial Distributary	.. 15,000
Monsoon Distributary	.. 7,500

The accompanying two tables give losses in cusecs per mile (as well as per 100 Rft.) and capitalized values for loss by percolation for contour and ridge canals for perennial, non-perennial and monsoon channels applicable to conditions obtained in Deccan.

It is true that the duties mentioned above may not hold good in a particular channel. But the idea underlying these tables is to help the designers in making some assumptions that agree with practice. Unless therefore more definite information is available for a particular tract these tables should be useful for designing purposes in general.

DISCUSSION ON ECONOMICS OF DECCAN CANALS— SELECTION OF WATER DEPTH.

Mr. Dildar Hosain, Mr. K. R. Sharma and Rai Bahadur W. C. Chopra offered remarks and asked questions and further information on certain points after the paper was introduced by Rao Saheb N. S. Joshi at the 20th Annual Session at Lahore. These three gentlemen did not send a summary of their remarks. It could not therefore be printed. However, the points would be clear from the replies to the remarks and queries, given by the Author as they are self evident.

The remarks of Messrs. S. Dutt and R. B. Chakravarty (Bengal Centre) are given below :—

Mr. S. Dutt : Since the silt theories of Lacey and Kennedy do not apply to the conditions prevailing in the Deccan, I would like to be informed if any other theory has been established after necessary experiment and research indicating the behaviour of silt particles in the Deccan and allied tracts. There may be no troubles due to deposition of silt or scour now, as the sub-surface stratum is rock and the loose surface soil is of small depth, but the necessity of knowing the behaviour of silt cannot be gainsaid.

The empirical formula $d = \sqrt{W}$ given on page 210 of the paper where d = rise or fall above or below the level of the falling contour and W = the average width of the canal requires verification by actual examples from works in existence. It is necessary to know to what extent this formula is dependable in determining the depth of water in canals which is the major issue in this paper.

The cost of unit area of land in different parts of the country being different, the ratio of the cost of land to that of the works will not be the same in different areas. Hence the comparative statements of cost on page 214 and page 232 will be materially different for different places.

The economics of Deccan Canals as given by Rao Saheb N. S. Joshi will have very little application in alluvial tracts like Bengal, since the question of silt which is the controlling factor in such countries, has been entirely kept out of view.

Mr. R. B. Chakravarty enquired about the cost of land necessary for the canal.

The Author (in reply): Regarding the remarks by Mr. Dildar Hosain, the method for determining the water-depth envisaged in the paper, applied generally to all the area having igneous rock, particularly the Deccan trap. It held good in all cases where conditions were similar to those, described in the paper, with regard to the general layout of the country, *i.e.*, alternating ridges and valleys (as in Bombay Deccan) with hard rock only a few feet below the ground-level. In general it may be said that the theory applied to all tracts having rocks of igneous formations or better still to "Non-alluvial" tracts.

Regarding the range of discharge, the tables published in the paper were worked out for discharges from 50 to 6000 Cusecs. But what is important is that the paper enunciates a method that should be followed in determining the depth for any given discharge and in the case of larger discharges it should be easy for any one to work on lines similar to those in Appendix No. 4 of the paper, with due consideration for local conditions such as allowance for losses in transit, rates and deviations.

Regarding the hydraulic gradient of 1 in 4, the theory was fast losing ground. Observations show that the thin silt-film forming on the wetted perimeter of canals and the berm which forms a thick carpet on which the film rests, serve as barriers against percolation through banks. As will be found on a reference to the Author's Paper on Losses in transit through Deccan Canals (Paper No. 180 for 1938 Bombay Engineering Congress), the major portion of water lost by percolation finds its way through cuttings and not through banks. Observations on Canals in the Bombay Deccan show that a hydraulic gradient like the theoretical 1 in 4 does not exist in the banks of canals, so long as the water level is kept below the silt-film, *i.e.*, below the normal full supply level. It is worth noting that the Nira Left Bank Canal in the Bombay Deccan was constructed with ordinary earth for side and full banks with no special core in them for reducing percolation, and still it is known as the most water-tight canal in that tract.

It is probable that the existence of a hydraulic gradient of 1 in 4 is surmised by Mr. Dildar Hosain as a result of slips in banks made of bad earth. If so, the provisions of a cover over the assumed hydraulic gradient line of 1 in 4 is hardly the cure. It is well known that banks continue slipping and keeping wet if constructed of *chopan* soils (salty soils) even if they were constructed with a much flatter hydraulic gradient. It is the choosing of the soil for constructing banks that is faulty in such cases.

But even supposing that the theory of a hydraulic gradient of 1 in 4 were correct and that banks were to be designed accordingly, the areas of embankment will need increase only in the case of upstream banks as shown in the tables on page 2?6 of the paper. The table for D/S banks as well as the whole table on page 226 for small canals, remains unchanged.

Further the change in question will not seriously affect the estimates on the lines of those in Appendix 4, and the findings will still remain unchanged. Mr. Dildar Hosain will find this if he actually works out the figures for any typical case. On the other hand, if he finds that the areas of the sections of banks do change very seriously, and actually affect the figures of costs, the proper course for him is to change the estimates likewise and find out the most suitable figures for those altered conditions. In this connection, the Author requests attention to the paragraph with the title "General Conclusions" on pages 217 and 218 of the paper and to the following sentence in particular.

The point of importance, to be borne in mind however, is that even with these changes, the cost of first construction plus that of losses in transit (capitalized), is not the same for all water depths, and that a particular depth gives a minimum cost depending upon the factors explained. Any other water-depth will mean money not properly utilized..... The main conclusion therefore still remains unchanged though actual depth adopted may (according to local conditions of rates and features of the country) change to some extent.

Mr. Dildar Hosain gave an example of the Canal taking off from the Nizam-Sagar reservoir in Hyderabad and showed that the formula $D = 0{\cdot}90 \sqrt{A/5}$ indicates a depth of 14 ft. for a discharge of 3000 cusecs and a velocity of 2 ft. per second. It is regrettable that he has adopted this formula in spite of

what the paper says from page 211 onward. The said formula would hold good only if the whole length of the Canal were in high full bank. Actually as this is not so, the formula does not hold good and should not have been applied, but the depths shown in tables and graphs in Appendix No. 5 taken instead. It is to be noted that the tables give depths for given areas of waterways. The Canal at Nizam-Sagar is actually designed with a velocity of a little over 3 feet, the discharge being 3000 cusecs. The area of water-way is therefore 1000 sq. ft. The tables in Appendix 5 show that the most economic water-depth for this case is 10 feet. It is gratifying that the actual depth adopted for that Canal is exactly the same and the instance of the Nizam-Sagar Canal quoted by Mr. Dildar Hosain therefore, serves as an example in support of the theory and the tables in Appendix No. 5.

Had however the Canal been designed with a velocity of 2 feet per second, the waterway-area required would have been 1500 sq. ft. and the most economic depth of water for these conditions would have been about 12 feet and not 10 feet.

Mr. Dildar Hosain has pointed out that the depth of water for a discharge of 7500 cusecs (a velocity of 3 feet per second) as indicated by the formula $D = 0{\cdot}90 \sqrt{A/5}$ would have been 21 feet, and that this looked absurd. This is obviously due to an incorrect use of the said formula as pointed out already. Mr. Dildar Hosain further points out that a large capacity would be lost in the reservoir if a canal were designed with that depth. The fallacy of the argument lies in the fact that a Canal with 7500 cusecs as discharge would need the contents of the reservoir to be about 90,000 M.C.Ft. Such a reservoir will need a depth of water in the reservoir equal to about 300 feet. A depth of 20 feet at the bottom of such a reservoir forms a negligible part in the contents and is therefore unimportant.

His figure of 21 feet is however based on wrong premises and on the use of a formula not meant for the purpose to which he puts it. He should work out the depth on the lines indicated in the paper from page 211 onward. The same is true of the cost of outlets and syphons mentioned by him.

Regarding the remarks by Pandit K.R. Sharma, publications in the past did not show any method of selection of water depth for Canals in the Bombay-Deccan and the Author has given an actual method with examples in support. If Pandit Sharma or anybody else, could successfully work out a mathematical formula, the Author would heartily congratulate the finder of the formula.

Pandit Sharma was kind enough to explain in detail, the lines on which losses of water in transit occured in Punjab Canals. Though these detailed explanations were very interesting, they have unfortunately no bearing on the problem of the design of Canals in the Bombay-Deccan. As in the case of other factors, there was very little common between the canals in the two tracts so far as principles of design were concerned. It will however interest Pandit Sharma and some other members of the Association to know that, in his paper No. 180 read before the Bombay Engineering Congress, on losses in transit through Deccan Canals, the Author has shown that figures of losses for those Canals are in agreement with what is known on the Bombay side as "*The Crump's Theory*" and which the Author now understands is the "*Sharma-Crump Theory.*"

Rai Bahadur W.C. Chopra wanted to know the range of discharges for which the Author's theory worked. So far as the tables actually worked out in Appendix No. 5 of the paper were concerned, they showed depths for discharges ranging from 50 cusecs to 6000 cusecs. That did not however mean that the method enunciated in the paper did not hold good for higher discharges. The Author has however not worked out depths for discharges higher than this but expects that an engineer designing such a canal will follow the lines explained in the paper and prepare standardised estimates on lines of Forms A, B & C in Appendix No. 4 for various depths in order to determine the optimum.

Regarding the formula $d = \sqrt{W}$ on page 210 of the paper, this was based on the data of the five important systems of Canals in the Bombay-Deccan namely the Nira, the Pravana, the Mutha, the Godavari and the Girna Canals. It is possible that the formula may differ for different conditions and the Author would then advise the particular designer to base his standardised estimates in Forms A, B & C in Appendix No. 4

on the changed formula for deviations for the local conditions. The important fact remains that whatever the formula for the deviations may be and whatever the rates prevalent in that locality may be, there was an optimum water-depth for a given discharge which proves more economical than any other depth either higher or lower. It is this principle, which the Author along with the detailing of factors involved in the economical designs of Canals, and the method enunciated by him in the practical application of these, considers as the most important part in his contribution.

The Deccan Canals usually fall under three categories. The perennial Canals were those which supplied water throughout the twelve months. Perennial crops like sugar cane and fruit have to be irrigated for all the twelve months at intervals of ten days. Such Canals were fed from the floods of the river in the four months from June to October. The river flow falls down considerably in the winter season, *i.e.*, during October to February and is insufficient to supply the full demand on the Canal in that period. In the hot weather the discharge of the river is nil. Hence in order to supply the requirements of the Canals in that season and to supplement those in the Rabi season, water has to be stored in large reservoirs specially constructed for that purpose.

In certain Canals it is not found desirable to construct reservoirs large on the score of economy and returns. In such cases water is supplied to Canals only during the four months of the monsoon and for the winter. Such Canals are called "*Two-Seasonal Canals*", and are fed by pick-up-weirs called *Bandharas*. Further, there are Canals taking off from streams where the winter-flow too is negligibly small. Such Canals flow during monsoons only and are called "*Monsoon Canals.*"

This description will further help to show an additional item of difference in the two sets of Canals namely those in the alluvial plains of upper India and those in the igneous tracts of the Deccan.

Regarding the closures mentioned by Rai Bahadur Chopra, there were no long closures extending for months together in

the case of Deccan Canals. The Canals there had rotations of 10 days and usually ran for 7 days actually with closures of 3 days in every rotation.

The Deccan Canals are usually contour Canals and they command the area between themselves and the river. The side-banks on the riverside is known as the down-stream bank while that on the uncommanded side is known as the upstream bank.

Mr. S. Dutt has raised 4 points. Regarding the first, the Author would refer Mr. Dutt to the figures given in item 3 on page 199 of the paper where he will find that the silt in Deccan Canals is extremely poor in quantity and colloidal. Hence the difficulty of silting on the lines of inundation canals in alluvial tracts does not arise.

Regarding the equation $d = \sqrt{W}$, Mr. Dutt will find a theoretical proof in figure No. 5 which the Author has verified with actuals.

The difficulty regarding actual data lies in the fact that personal factors have crept in the alignments of different canals. Thus to take a concrete example, the Nira Left and the Nira Right are two canals, which though they run in similar area, have been aligned with quite different ideals. The former is aligned with a view to economy while the latter is guided more to straightness in alignment at the cost of economy. It is useless comparing these two canals for the rule $d = \sqrt{W}$. The same holds good for other canals also and hence, simply collecting data for all these canals does not help and one has to depend upon theoretical proofs as in figure No. 5 of the paper. The Author may, however, publish the data, he has, on some future occasion.

The Author would, in this connection, invite Mr. Dutt's attention to the concluding paragraph of his paper, which explains the point under reference further. It is hoped that, Mr. Dutt is not trying to apply that rule with conditions obtained in Bengal Canals, as obviously that will be a mistake.

Regarding the cost of land, Mr. Dutt is referred to the reply given below to the remarks of Mr. Chakravarty.

Regarding his remarks, that the Economics of Deccan Canals will have no application in alluvial tracts like Bengal, the Author has made that amply clear in his paper and hardly requires repetition. That has been, in fact, the burden of the Author's publication in question, as well as his publication of the last year, "Lacey's Theory & Deccan Canals."

Regarding the remarks by Mr. R. B. Chakravarty (Bengal Centre), the pre-canal costs of lands in the Bombay Deccan are very small; the average rate per acre being only 50 to 60 rupees whereas their value, after irrigation came in, becomes four-fold or more. Again the land required does not vary directly as the bed width of the canal; thus a canal with 200′ width and 2′ depth of water will not be 5 times as much as that for a canal with 40′ width and 10′ depth. It is only about twice as much, as large width is required for side banks in the case of the latter alternative. The result is that in the Bombay-Deccan the cost of the land to be paid is only about 5 per cent of the value of actual construction and is therefore negligible. Where, however, valuable land is involved, it should be included in the cost of first construction.

The Author is highly obliged to the speakers who had taken part in the discussion and thanks them sincerely for the interest taken by them in the paper. He would request similar occasions in future which will result in giving the Author additional impetus in his technical pursuits.

HYDRAULIC MODELS AND THEIR APPLICATION TO AMERICAN FLOOD CONTROL & RIVER TRAINING PROBLEMS

BY

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(Not an Institution paper, but read at the Bengal Centre.)

Introduction :—It is now fully sixty years since Fargue built the first true river model, more than a half a century since Osborne Reynolds and Vernon Harcourt conducted their well-known experiments and forty years since Germany started her famous "Flussbau" laboratories and with them the development of river model research. In these circumstances it seems little short of astonishing that as recently as 1928 the United States of America had not a single institution equipped to study the countless river problems of that vast country.

The disastrous Mississippi flood of 1927 with its toll of 313 lives and loss and damage exceeding 280 million dollars finally roused the country and as a result of the untiring efforts of that great hydraulician John R. Freeman, the U.S. Waterways Experiment Station was opened at Vicksburg in 1931. It was received with little enthusiasm by engineers on the Mississippi River for most of them still held the opinion that the river was its own laboratory—incidentally a most expensive one. Two works alone had accounted for twenty-two million dollars. In opening up the South Pass to ocean going vessels twenty million dollars had been spent before satisfactory results were obtained. Experimenting with permeable dikes had absorbed a further two million dollars.

In agreeing somewhat reluctantly to the establishment of the Waterways Experiment Station the Chief of Engineers suggested that "On occasion, questions relative to the flow of

water can be worked out by small-scale experiments. Such experiments may be useful in some of our lock and dam designs." He could little have realised then what an important part the Experiment Station was destined to play, and that within the space of five years it would be undertaking the solution of river and harbour problems submitted from every section of the United States.

With the Waterways Experiment Station successfully launched it was not long before the Universities commenced enlarging their hydraulic laboratories. Up to that time they had mostly been of the simple character needed for undergraduate student demonstration. At the University of Iowa, model experiments connected with the construction of locks and dams in the Upper Mississippi River were put in hand. The University of California started work upon a large tidal model of the Columbia River; the Bureau of Reclamation rapidly developed its existing hydraulic structures laboratory ; a new experiment station was opened at Knoxville in connection with the Tennessee Valley Authority project, and so development progressed. To-day America has approximately forty laboratories working upon practical hydraulic engineering problems, no less than ten of which are equipped to undertake river model experiments.

This indicates the remarkable progress of hydraulic model experimentation and most definite recognition of its usefulness. It may be said without exaggeration that at the present time no major hydraulic engineering project is undertaken in the U.S.A. until a comprehensive model study has first been made. By following this procedure it is estimated that many millions of dollars which might otherwise have been wasted upon ill designed and unprofitable works are now being saved annually.

During the auhtor's tenure of the Commonwealth Fund Service Fellowship, worked for nine months in the hydraulic laboratories of the University of Iowa and was attached to the U. S. Waterways Experiment Station for six months. For a further four months, facilities were granted which enabled him to visit eleven other important hydraulic laboratories including those of the Bureau of Reclamation, Tennessee Valley Authority, the National Hydraulic Laboratory, Washington,

D.C., the Universities of California, Cornell etc. At each of these Institutions he found the staff most enthusiastic about the results which were being obtained.

The main purpose of this paper is to show how indispensable model experimentation has become to engineers engaged in flood control and river training work, also to convey some idea of the scope and nature of experiments recently undertaken in America.

In certain provinces of India too, the importance of model investigations is to-day fully appreciated, and although the bulk of experimental work hitherto undertaken has been connected with the design of irrigation structures, there is at the present time a rapidly increasing number of river problems being solved with the aid of hydraulic models. Further reference will be made to these experiments at the end of this paper.

Types of Models.

The various types of models employed in the solution of flood control and river improvement problems may be broadly grouped as follows :—

1. Structural Models—including overfall dams and spillways, syphons, outlet sluices, locks and sluices etc.
2. River Models—in which tidal effects are non-existent or small enough to be neglected.

   This group may be divided into—

   (a) Fixed bed models,

   (b) Movable bed models.
3. Tidal Models.

In Group 1 the problems presented may simply be the determination of discharge capacity or as is frequently the case the restriction of scour and erosion immediately downstream of the structure. If the latter, the downstream portion of the model is provided with a movable bed. In all these problems, gravity may be considered as the controlling force.

Group 2 (a).—Fixed bed models are principally employed in flood control investigations to determine the effect upon water levels of cut-offs, the limits of backwater and in general

problems involving water surface elevation control. In this type of model channel and overbank friction is of primary importance.

In Group 2 (b) typical problems include investigation of the effect of contraction works, dredging, and structures such as bridges, weirs, barrages, etc. upon the regimen of the rivers; the prevention of bank erosion caused by river meandering, etc.

In this type of model it is seldom possible to obtain quantitative results; however for the purpose of comparing the effects of several proposed plans in order to select the most suitable, the movable bed river model gives most valuable information.

In Group 3 are included the several types of tidal models, most of which have movable beds. Tidal models differ principally in the method adopted for generating the tides and in the extent of reproduction of the tidal prism. If the whole tidal prism is modelled, tides may be produced by the rise and fall of a plunger or by a tide distributor similar to that employed in the Columbia River model built at the University of California.

When only a small portion of the tidal prism is modelled tidal fluctuation is most generally produced by the so called "reversible flow" method otherwise by the "reservoir" method. In the former, automatic tidal gates are now being used at Vicksburg with excellent results. Details of the apparatus employed will be described in a subsequent paragraph. The reversible flow method is particularly well adapted to problems in which the tidal range is small and water depths in the area under investigation are relatively large.

Tidal model studies involving volume of flow, salinity and other information of this kind ordinarily require the reproduction of the whole tidal prism. In such models a relatively small scale with a high degree of vertical distortion becomes necessary.

When however the problem is one involving bed load movement it is generally necessary to reproduce the problem area to a comparatively large scale in order to obtain accurate results. The tidal problems dealt with at the Waterways Experiment Station to-date have been of the latter kind, scale requirements having made the reproduction of the entire tidal prism impracticable.

Tidal model experiments necessitate the reproduction of a larger number of factors than are found in ordinary river models and on that account are usually difficult to conduct. In addition to tidal fluctuations which may themselves be very complex, such phenomena as littoral current and drift, wave action, wind action, coagulation of colloidal matter by salt water, etc. are frequently introduced and must be satisfactorily simulated.

In addition to the three main types *viz.* Structural, River and Tidal models required in the solution of flood control and river improvement problems a combination of the first two types is not uncommon and is usually a difficult study. For example a navigation lock and dam (American type) or an irrigation barrage will introduce complications when one comes to consider the effect of the river section distortion upon the flow through the structure. The difficulties encountered in these combined-type models have been discussed in detail by Mr. C. C. Inglis, in his recent paper "The Use of Models for Elucidating Flow Problems."

TYPICAL MODEL EXPERIMENTS.

1. *Structural Models—Boulder Dam Spillways.*

For the Boulder Dam project it was required to construct two spillways, one on either side of the gorge, each capable of discharging 200,000 cusecs with a fall of nearly 500 feet.

Four entirely different forms of spillway were tested in the laboratories of the U.S. Bureau of Reclamation, each with numerous modifications before the final design was evolved. The first experiments were made upon a model of a "glory hole" or shaft spillway to a scale of 1 : 60. The tests indicated that it would be very difficult to get the water to flow over the crest at uniform depth throughout its length, and obtain smooth conditions of flow down the shaft and through the tunnel. This type was therefore abandoned in favour of a side channel spillway discharging into an inclined tunnel.

The first model of this type was given an equivalent crest length of 700 feet. This was replaced by a shorter spillway of the same type and having a large Stoney gate fitted at the upper end. This was succeeded by another side channel model with drum gates on the crest, but no gate at the end.

Experiments were then carried out with a number of different models of this type to a scale of 1: 60. Simultaneously tests were run on similar models having scales of 1: 20 and 1: 100. Remarkably close agreement between all sizes resulted, leading to considerable confidence in the accuracy of the tests. Fig. 1 (a) shows the 1: 100 model and Fig. 1 (b) one of the spillways actually under construction.

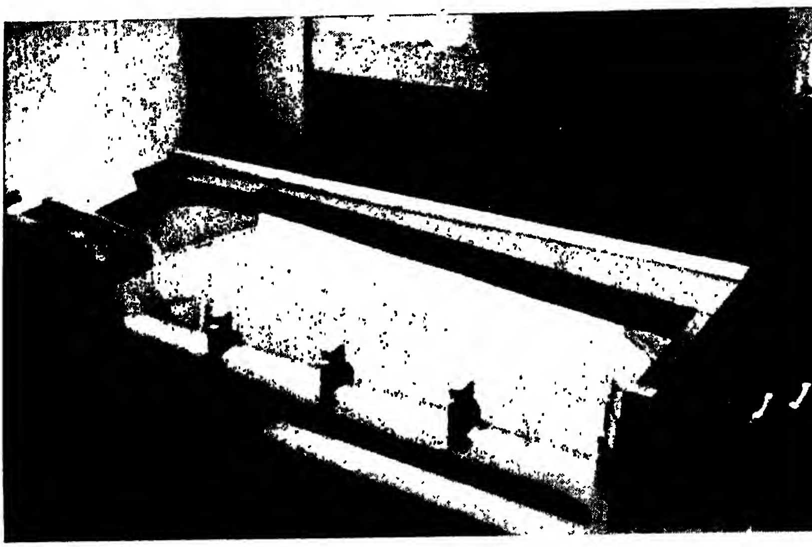

Fig. 1 (a)

Fig. 1 (b)

Sufficient has been said to illustrate the thoroughness with which the Boulder Dam spillway tests were conducted. Models play an indispensable part in spillway design and result not only in reduced construction costs but also in increased hydraulic efficiency. It is therefore easily understood why now-a-days the Bureau of Reclamation invariably base the design of their spillways upon model tests. During the period 1931-35, spillways of no less than fifteen different dams were tested in the laboratory.

Alton Lock & Dam, Mississippi River.

In connection with the development of a navigation channel with a minimum depth of nine feet, a series of lock and dams have been constructed in the Upper Mississippi River. Before building these structures detailed model experiments have been conducted under the direction of the U. S. Engineer Department at Iowa University, and were in progress during the time the author was there.

In the case of the Alton Lock and Dam an unusual problem was presented owing to the fact that at 800 feet downstream of the site selected for the dam, the Mississippi is crossed by a railway bridge and 200 feet still further downstream by a highway bridge. It was therefore necessary to determine the most suitable design for the stilling basin and the best location and method of operation for the roller and tainter gate bays so that scour at the bridge piers could be reduced to a minimum. At the same time it was desired to ascertain the best means of preventing siltation in the lock approaches, the effects of the proposed construction cofferdams and the backwater effect of the completee structure. The study was of further interest inas-much as it involved tests with a combined structural and movable bed river model. Judged by to-day's standards the design of this particular model could perhaps be improved, however in 1934 it marked a decided advance upon similar studies hitherto undertaken.

Built to scale of 1 : 400 horizontal and 1 : 60 vertical it reproduced a reach of the Mississippi River from mile 203·5 opposite the city of Alton to mile 196·4 near the point of confluence with the Missouri River. The bed was moulded in a carefully selected fine sand which responded to the action of the water in the same manner as did the sand bed of the river itself.

A second model to a scale 1: 25 was constructed to represent a longitudinal section of the river approximately 400 feet wide through the dam and bridge section and including 8 tainter gates, two piers of the railways bridge and one pier of the road bridge.

Space does not permit of a description of the various results obtained. Brief mention is however made of the stilling basin experiments which were conducted in a most thorough manner.

Model tests conducted prior to 1934 had established that the hydraulic jump or standing wave obtained under proper conditions is an extremely effective means of dissipating the excess energy of a stream of water. To be satisfactory however a stilling basin must have a depth below tailwater level not less than the minimum required to create a complete and stable jump near the aperture of the gate or crest of the dam under the worst conditions. Furthermore it must be of sufficient length to complete the transition of flow before the water leaves the basin.

Earlier Iowa experiments had shown that the jump can be effected in a shorter length of stilling basin if baffle piers of the proper size and spacing are provided on the apron. Similar tests with baffle piers, or "blocks" more recently conducted at the Lahore Research Institute and elsewhere, bear out this conclusion.

Fig. 2 illustrates the reduction in length of the Alton stilling basin and the extent of the downstream pitching required for various ratios of downstream to upstream water depths.

The design finally recommended for the stilling basin is shown in Fig. 3.

2. *River Models—Fixed Bed Type—Helena-Donaldsonville Model.*

The world's largest and most costly river model is of the fixed bed type. Built at the U. S. Waterways Experiment Station, Vicksburg during 1935 it reproduces the lower 600 miles of the Mississippi River, and an area of 16,100 square miles. With scales of 1 : 2,000 horizontal and 1 : 100 vertical it measures 1,050 feet in length and 107 feet average width. It includes not only the limits of the Mississippi

backwater influence but also the areas subjected to spill by operation of the floodways provided in the revised Mississippi Flood Control Project. Fig. 4. shows a portion of the model under construction, and Fig. 5 an up-stream view of the completed model with the Gulf of Mexico in the foreground.

It is equipped with a field telephone system flood lights, 4 automatic recording gauges, 186 gravity gauges, 5 entrance and 2 discharge weir boxes.

The model took four months to build and cost $ 133,425 or Rs. $3\frac{1}{2}$ lakhs approximately. To us in India this may seem an absurdly large sum to spend on the construction of a model, but when one considers that the revised plans for flood control on the Lower Mississippi River involve the expenditure of 500 million dollars or Rs. 133 crores and that a saving of one crore at least may reasonably be expected to result from the experiments it will be seen that this model should prove a particularly good investment.

After the 1927 Mississippi Flood a comprehensive flood control plan was adopted. This included the construction of several floodways, extensive corrective dredging, and a series of cut-offs which would reduce the length of the Lower river by roughly one hundred miles. The main purpose of the Helena—Donaldsonville Model was to test these works which by 1935 were nearly completed and ascertain the effect of an equivalent 1927 flood, and also the super-flood which the improvements were designed to meet, if they occurred under 1935 channel conditions. Would the levees hold these floods if not where would overtopping be likely to occur?

The 1929 Mississippi flood was the first major flood to be completely confined within levees, accordingly it was used as the basis for adjustment and verification of the model. After moulding the channel to 1929 conditions adjustment tests at selected constant discharges were run for nearly two months

during which time the model was operated for from 9 to 16 hours daily with an additional 8 hours for analysis of the results obtained and for making the adjustments indicated. Before tests commenced a thorough examination of the model was made by experienced field engineers from all the Engineer Districts concerned, and modifications where necessary were made under their advice.

Upon satisfactory completion of the adjustment runs, verification tests were then started, their object being to check the model's ability to reproduce the known flood levels, correct form of hydrograph and time of travel of the 1929 flood wave. It was specified that the stage heights should be accurate to within one foot depth in the river—this being quite considerable accuracy with depths up to 100 feet in the flood channel. Incidentally the required agreement was obtained at all except two of the main river gauges.

By March 1936 when the author left Vicksburg the programme of tests was about half completed and had supplied most valuable information. At that time it was little thought that a major flood of 1927 dimensions would follow a year later, and it says much for the value of the experiments and the measures adopted as the result of their indications that the 1937 flood passed down the Mississippi without the occurrence of a single breach in the levees, although this same flood a few days earlier had caused almost unprecedented chaos in the Ohio valley.

Immediately below Cairo, flood levels rose even higher than in the 1927 flood. This however had been predicted by the model and suitable steps had been taken to meet it. Further down-stream the effectiveness of the cut-offs in lowering flood levels at points of importance was undoubtedly proved. At Arkansas City for example the discharge was between 500,000 and 700,000 cusecs in excess of that of the 1929 flood and yet it passed at the same level. At the crest of the flood approximately 2,150,000 cusecs were carried at a stage of 54 feet. In

1929 only 1,400,000 cusecs were passed at this height. At Vicksburg the channel carrying capacity had increased by 370,000 cusecs for stages above 45 feet. New tests with the Helena—Donaldsonville model are still in progress and it will probably be a long time before its usefulness is exhausted.

Movable Bed Type—Fort Chartres Model.

This is the most common type of river model and is considerably more difficult to design and operate than the fixed bed model. It will be explained in a later para under "Design of Hydraulic Models" how during the last two or there years far-reaching changes in the design of movable bed river models have taken place at Vicksburg. Accordingly the Fort Chartres Model built in 1933 and therefore one of the earlier movable bed model studies conducted at the Waterways Experiment Station, is not truly representative of its type at the present time. It is however typical of the many channel improvement problems which have been submitted from the Mississippi River to the Experiment Station and for which a most satisfactory solution has been obtained. It illustrates too how indications given by the model have been confirmed in the prototype.

The experiment was conducted to determine the best method of realigning the low water channel by means of permeable pile dikes in order to obtain improved navigable depths over the crossing at Fort Chartres East.

A stretch of the Mississippi River for 11 miles up-stream and 6 miles down-stream of the crossing was represented in the model and scales of 1 : 1,000 horizontal and 1 : 125 vertical were adopted. The bed was then moulded to a river survey which had been made a few months before the experiment began. Discharges and water surface slopes in the model were adjusted to conform to conditions existing in the river, and an operating chart was prepared from river data with stages rising and falling by 5 foot intervals. Four different tests were conducted each beginning with the model moulded to represent the river conditions existing at the time of the October 1932 survey.

Fig. 6 shows the model in operation the direction of the surface currents being indicated by confetti. Fig. 7 illustrates the configuration of the bed after a run had been completed and the model drained.

Fig. 6.
Fort Chartres Model in operation.

Fig. 7.
Model Bed at end of Run.

The unsatisfactory condition of the river bed during October 1932 is clearly shown in Fig. 8(a). Fig. 8(b) shows the improvement plan recommended by the Experiment Station and Fig. 8(c) the plan with very slight modification in the process of execution and the condition of the river by March 1934. The channel was clearly developing along the desired alignment and adequate depths for navigation were then being obtained.

In the past, as already explained, large sums of money had been spent in building Mississippi dikes and other contraction works most of which were quite ineffective owing to their faulty location. This hit and miss method has to-day been entirely superseded by laboratory experimentation and only very rarely now does the model fail to point to a satisfactory solution.

3. *Tidal Models—Chesapeake and Delaware Canal Model.*

In connection with a project for enlargement of the Chesapeake and Delaware Canal, an experiment was conducted at the Waterways Experiment Station to discover practical means for eliminating the heavy shoaling which persisted at the Delaware River entrance to the canal. It was desired to ascertain the cause of this shoaling and the movement of shoal material.

Fig. 9 gives the layout of the model showing template and rail locations and shore line, etc.

This particular experiment is of interest in as much as it was the first of the Vicksburg tidal models to be operated by automatic tide gates. These were located at Stony Pt., New Castle and the western extremity of the length of canal reproduced in the model. These gates were operated electrically in such a manner that the tidal cycle in the river and canal could be accurately simulated to scale in the model.

The model was built to scales 1 : 800 horizontal and 1 : 80 vertical. As a means of verification the movable bed was moulded to an earlier survey and the model operated through a sufficient number of cycles to reproduce the shoaling in the mouth of the Canal. As a further means of verification the cut dredged across the bar above Reedy Is. during 1932 was simulated and the resultant current directions and velocities were observed in the model and compared with those which occurred in the river.

Upon completion of the verification tests the proposed enlarged canal was reproduced and the model tested with various straight and curved jetties suggested by the local Engineer District in position.

As in the case of the other Vicksburg models described above, the Chesapeake and Delaware Model was constructep out of doors, but for protection against wind a temporary housing was erected around it. The dimensions of the model were approximately 115 ft. in length by 20 ft. in width. The total quantity of water used was 6 cusecs.

The automatic tidal apparatus used in this experiment consisted of the control mechanism, tide gates and recording drums.

From data observed in nature a tidal curve representing a complete tidal cycle was drawn to the linear and time scale of the model and then reproduced as a rotating cam. The cam system was driven by a small electric motor through a gear train in such a manner that its period of rotation corresponded to a complete tidal cycle at the time scale of the model.

In the Chesapeake and Delaware model which required more than one automatic tide gate, the cam controls were kept in synchronism by a common driving shaft. During their rotation the cams transmitted a vertical movement to the cam followers attached to which were two electric contact points whose circuits lead to a control board. A third contact, the vertical movement of which was actuated by a float, was placed between the cam contacts. Any movement therefore of the cam follower caused electrical contact to be made between the float contact point and one of the cam contact points, thus completing the electric circuit and resulting in an up and down movement of the tide gate.

When the water surface at the float reached the level required by the tidal curve, the float was momentarily in equilibrium, no electrical contact was made and the gate remained at rest. This continued until contact was again made either due to movement of the cam or of the float.

The control board was provided with signal lights which showed exactly what the gate was doing, also necessary protection fuses and safety switches. The tide gate consisted of a vertical steel plate sliding in a rigid steel frame. It was lifted and lowered by means of a screwed shaft coupled to the driving motor through suitable reduction gearing. The motor was of a special type capable of being reversed continuously without overheating. The water level recorders were located at selected points in the model with the object of recording the water surface in the form of hydrographs. They were of the drum type and operated by small electric motors properly geared to give the required speed of rotation. Two pens were used, one stationary and indicating regular periods of time, the other attached to a float and recording the hydrograph.

Fig. 10 gives a general view of the model and Fig. 11 the control apparatus, tide gate and recording drum at New Castle.

Fig. 10.

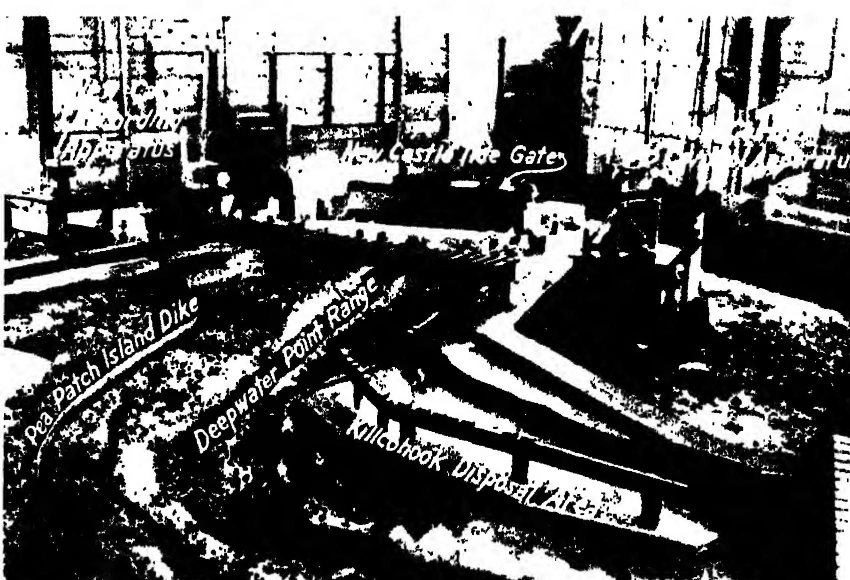

Fig. 11.

Design of River and Tidal Models.

It is not proposed in this paper to discuss the fundamental relationships upon which the design of hydraulic models is based, but rather to draw attention to some of the more important practical points.

In river and tidal problems the flow in the prototype is turbulent. It is therefore necessary that the model shall have such dimensions that when in operation its Reynold's number represented by $R = \frac{Vr}{\nu}$ where V indicates the velocity, R a linear dimension—hydraulic radius in the case of open channels, ν the co-efficient of kinematic viscosity of the fluid, is within the range of turbulent flow.

As to what should be this value of Reynold's number there appears to be some difference of opinion.

Gibson[1] states that in a model of a straight uniform reach of a river or canal, turbulence is attained if the Reynold's number exceeds 1,500. On the other hand values as high as 90,000 have been used in the large river models built at the Central Irrigation and Hydradynamic Research Station, Poona.

The nomenclature adopted at Vicksburg, and the ratios commonly employed in river model design are as follows :—

L = length or breadth ; D = depth or head ;

S = slope ; P = wetted perimeter ; A = area of cross section ; R = hydraulic radius ; V = velocity ;

T = time and Q = discharge.

The subscripts "m" and "n" represent the corresponding values in the model and in nature.

$$\text{Length scale} = l = \frac{Lm}{Ln}$$

$$\text{Depth} \quad ,, \quad = d = \frac{Dm}{Dn}$$

[1] Tidal and River Models—Prof. A. H. Gibson
Supplement to No. 8 Journal Inst. C. E. 1935-36.

Area ,, $= a = \dfrac{Am}{An} = d \times l$

Slope ,, (distortion) $= s = \dfrac{Sm}{Sn} = \dfrac{d}{l}$

Wetted Perimeter scale $= p = \dfrac{Pm}{Pn}$

Hydraulic Radius scale $= r = \dfrac{a}{p}$

Velocity scale $= v = \dfrac{Vm}{Vn}$

$$= \dfrac{\dfrac{1{\cdot}486}{Nm} \times Rm^{\frac{2}{3}} \times Sm^{\frac{1}{2}}}{\dfrac{1{\cdot}486}{Nn} \times Rn^{\frac{2}{3}} \times Sn^{\frac{1}{2}}}$$

$$= r^{\frac{2}{3}}\ S^{\frac{1}{2}}$$

assuming $Nm = Nn$. (Found to be approximately correct in the majority of movable bed models operated at Vicksburg).

Discharge $= q = a \times v$

Time $= t = \dfrac{Tm}{Tn}$

Bed Movement in River Models.

In the earlier movable bed river model studies conducted at the U. S. Waterways Experiment Station, Vicksburg resort was had to the application of the so called Du Boys Law

$$T = J.\ D.\ S.$$

Where T denotes the tractive force in lbs./sq. foot exerted by flowing water upon its bed, J the weight of water per cubic foot, D the depth of water in feet and S the slope of the water surface.

A sample of the river bed material obtained from the actual locality to be represented in the model was placed in a glass sided tilting flume and water was passed over it at any convenient constant depth. The slope of the flume was then increased keeping the water surface parallel to the bed

until general movement occurred. The tractive force was then calculated from the above equation. Inserting this value termed the "Critical tractive force" and the observed river surface slope in the Du Boys equation, the depth at which general movement began in the river was then determined. Dividing this by the model vertical scale gave the depth at which general movement must occur in the model.

A similar test was then conducted with the bed material to be used in the model and its critical tractive force was likewise determined. Inserting this value and the depth at which movement must occur in the model in the above Du Boys equation gave the required slope for the water surface in the model.

If as frequently happened the model slope obtained by distortion was inadequate "Supplementary" slope was given. With the introduction of lightweight bed materials, to which reference will be made in a later paragraph, supplementary slope is now generally unnecessary.

It now appears to be the opinion at Vicksburg that although the Du Boys equation is still useful as a means of expressing the results of their flume studies, it cannot be used satisfactorily to transfer results from flume to model and it almost invariably fails when one attempts to transfer the results from model to prototype. To-day after having conducted so many movable bed studies at Vicksburg past experience appears to be the principal guide in the selection of model slopes.

Bed Materials for River and Tidal Models.

The selection of a suitable bed material is one of the most important considerations in river and tidal model design. This is evidenced by the vast amount of research work which is being conducted on bed materials of various kinds at the present time.

It will be apparent that the size of the bed material cannot be reduced in the proportion of either of the linear scale ratios. Such a reduction would result in a powder of extreme fineness most of which would be transported through the model either on the water surface or in suspension and which could not

possibly reproduce bed scour and deposition as it occurs in nature. It is customary therefore to use a sand of approximately the same diameter as that found in the river or estuary or some other suitable material. This naturally causes a relatively greater surface roughness but fortunately in such movable bed studies its effect is inappreciably small.

At Vicksburg an extensive study of lightweight bed matetials has been in progress during the past three years and has contributed much to our knowledge of this important subject.

The more promising materials tested range from haydite with a specific gravity of 1·85 through semi-anthracite bituminous coals, flake pitch, wood rosin to gilsonites with a specific gravity of only 1·027.

Haydite is clay or shale burnt under patented processes then crushed, screened and graded. It is very hard and angular in shape. Gilsonite is a special brand of asphalt found in Utah, U. S. A. It contains 99·9% pure bitumen, is a natural unprocessed product, is very hard, slightly porous and is unaffected by heat up to 250°F.

As the result of this study of lightweight bed materials movable bed model design at Vicksburg has recently undergone a radical change. Whereas formerly sands with a specific gravity of approximately 2·6 were used as a bed material usually necessitating supplementary slope in the model to obtain proper bed movement, to-day crushed coal is mostly employed in movable bed river models and gilsonite in those tidal models requiring the simulation of light silt and mud movement. Distortion has been greatly reduced and supplementary slope is now generally unnecessary. In addition much of the undesirable riffling of the model bed, obtained when using sand, is prevented.

Haydite was used in several river models but has now been superseded by crushed coal. It is however still employed, with coal as the main bed material to mould non-erodible parts of the bed where rock or gravel is found. Formerly gravel was used but this produced excessively deep scour holes in its vicinity.

These lightweight materials possess certain disadvantages; for instance after continuous use it is frequently found that the apparent specific gravity and size of crushed coal and haydite have changed.

Gilsonite is expensive and difficult to use, for unless it has been previously soaked in water and then the model quickly flooded, air bubbles will adhere to the particles causing them to float to the surface.

Erodible Materials in Models.

It is frequently necessary to simulate eroding banks in a model and to this end exhaustive tests have been made at Vicksburg with many different kinds of composite erodible materials. To be really suitable the material should erode at an uniform rate, be capable of maintaining a steep angle of repose, be plastic, be little affected by air and sun when exposed at low stages and contain ingredients the particles of which when disintegrated by erosion will not hinder the free movement of the model bed material.

The nearest approach to such a material was found to be a mixture of sand and plaster of Paris, but being considered unsatisfactory its use has now been discontinued. The present practice is to mould caving banks with a mixture of crushed coal and plaster of Paris. It is not eroded by the velocities obtained in the model and will stand vertically. During the verification tests the banks are carved back by hand to correspond with the actual erosion in the river found by successive bank surveys. The coal then becomes a part of the bed material and the plaster of Paris being lighter is washed through the model. While the various improvement works are being tested, the same procedure is followed, the experience gained during the verification tests, as well as careful observation of the magnitude and direction of the current velocities along the river bank being the necessary guide.

Scale Distortion.

In river and tidal models the vertical scale is invariably made greater than the horizontal scale, resulting in geometric distortion. Its value is the vertical scale divided by the horizontal scale, which is the same as the slope ratio of model to prototype provided no supplementary slope is supplied.

Distortion varies greatly with the type of model, whether river or tidal, movable bed or fixed bed and other factors such as the size and type of the channel, etc. Since it produces a model channel whose hydraulic properties differ from those of the prototype it should be kept to as low a value as possible. For instance with movable bed models of the Mississippi River built to determine means of channel improvement by dredging it is now held that to obtain really satisfactory results the distortion should not exceed values of from 4 to 5. Formerly distortion values of 8 to 10 were usual with this class of model.

Opinion as to the maximum amount of distortion permissible in a river model differs considerably. It would seem that each authority sets as a maximum limit the greatest amount of distortion which he himself has found it necessary to adopt.

For movable bed river models the Waterways Experiment Station now regards a distortion of 6 as about the maximum working limit but prefers to keep it to 4 if possible.

Some tidal models particularly those in which the entire estuary has been reproduced, have been given some extremely high values of distortion. In the model study of the Severn estuary conducted by Prof. Gibson at Manchester University scale ratios of 1 : 8,500 horizontal to 1 : 200 vertical were employed, thus giving a distortion of 42·5.

In the Rangoon River tidal model built by Sir Alexander Gibb and Partners in London the horizontal and vertical scales were 1 : 9,068, and 1 : 192 respectively the distortion therefore being 42.

The Columbia River tidal model constructed at the University of California, Berkeley was given an even greater distortion of 56, the scale ratios being 1 : 3,600 horizontal and 1 : 64 vertical.

With models built to such small horizontal scales and provided with such high distortion values it is doubtful whether accurate reproduction is obtainable as a general rule. The banks and frequently extensive sand bars as well must be moulded rigid since the natural angle of repose of the model bank and bed material will be greatly exceeded. This obviously must tend to diminish the accuracy of the results.

The tidal model studies so far conducted at Vicksbrug have been such that the reproduction of the problem area only has been sufficient. This has permitted the use of very much larger scales, has required considerably less distortion in consequence and has doubtless led to greater accuracy of results.

Time Scale Ratios in Models.

With the exception of the movable bed river model the time scales ratios adopted in hydraulic model studies are obtained easily from the fundamental relationships.

Formulae for the determination of the time scale ratios of movable bed river models do exist but all without exception give values which cannot satisfactorily be used in the operation of the model. The formula $t = l d^{1/3} s^{\frac{1}{2}}$ (for notation see page 261) can be used as a preliminary guide but will be found to give time values which may be anything from twice to six times the value finally adopted.

It is evident that too many factors influence the time scale ratio in a movable bed river to permit of its determination by any formula. It is therefore unlikely that a suitable expression will be developed.

At the Waterways Experiment Station they rely entirely upon a time-scale empirically determined during the verification of the model, the same value being assumed during the tests of the proposed improvement works.

The general procedure adopted during the operation of more recent models in which crushed coal has been used as the bed material, has been as follows :—

First an arbitrary time scale is selected, say 6 hours in the model, equal to one year in nature during the period selected for verification. The complete hydrograph for the period of verification is then run at this scale and developments are closley observed. At the end of the run the plan of the model bed is then carefully compared with that of the river bed corresponding to the end of the verification period.

It is usually found that this procedure over-emphasises the effect of the higher stages or in other words the medium and high flood stages move so much bed material that the succeeding lower stages are of insufficient duration to restore the bed to its

proper shape. To remedy this, two expedients have been employed, the first being to vary the time scale according to the stage, increasing the period of low stages or decreasing the period of the high stages or both. The second method is to decrease the slope scale of the higher stages so that those stages may produce less effect. Frequently both methods are employed in the same model.

This procedure is necessary on account of the movability characteristics of the light-weight materials now being used. It is found that the application of the lower stages to the usual movable bed model of the Mississippi River which has crushed coal as its bed material results in very little movement. The application of the higher stages however results in violent movement due to the light-weight materials passing completely from the state of no movement to violent movement within the small range of tractive force or bottom velocities, whichever criterion is preferred, found in these models.

Construction of River and Tidal Models.

Preliminary Procedure. When a model study is required to be undertaken by the U.S. Waterways Experiment Station it is usual for the District Engineer concerned with the problem to submit an enquiry accompanied by general data, site plans, particulars of the problem, their proposals and a statement of the approximate sum of moneys available for the experiment.

The laboratory prepares a preliminary report, states whether the study is recommended and gives the approximate estimated cost. Usually too it states what further data would be required if satisfactory results are to be obtained and enquires whether such data can be made available.

If the District still desires to have the experiment made, and after further necessary maps and data have been received the Laboratory then sends a representative to inspect the site and collect further information which would be unlikely to be supplied by letter. He observes the particular features to be reproduced in the model and may if necessary make supplementary surveys. Generally the Director or Assistant Director of the Station makes this visit accompanied by the engineer who will be in charge of the experiment.

In the meantime a detailed estimate is prepared by the laboratory and is forwarded to the District. The model is then constructed, after which the verification tests are run.

The tests of the various improvement plans are then begun and at this stage it is usual for an engineer from the District to visit the Station. It is preferable if he can remain there while the more important tests are being run. Above all it is essential that the closest co-operation should be maintained between the laboratory and the field engineers and visits are exchanged as frequently as needed.

Collection of Data.

The success of a hydraulic model study depends very largely upon the adequacy and accuracy of the data supplied to the Laboratory, for one cannot expect to get more out of a model than one puts into it. This may appear a most obvious statement, nevertheless it is one which is not always sufficiently appreciated.

As an example of this, it may be mentioned that one model study conducted at Vicksburg while the Author was there must have failed completely if the Director, feeling that something was wrong, had not made a second visit to the problem site and discovered a certain important feature in nature which had not been made known to the Station—probably being considered relatively unimportant. This feature consisted of a submerged sill of loose stones which prevented an outlet channel from scouring.

The data usually required for a river model experiment consist briefly of the following :—

Topographic and hydrographic maps of recent surveys of the problem area, accompanied by river cross sections at frequent intervals. Hydraulic data giving detailed information regarding water levels, discharges, current velocities and directions, rainfall and runoff. Analysis of representative samples of bed and bank material and general geological information. Full particulars of any existing and projected embankments, revetment, contraction works, etc. Records of past channel conditions and dredging operations.

For a tidal model study the following additional data would usually be necessary:—

Tide curves for spring, mean and neap tides at several important locations in the channel. Samples of water for determination of its salinity at various points and under different tidal conditions. Suspended silt samples taken at a series of depths in the channel on the flood and ebb during spring, mean and neap tides.

Analysis of Problem.

From this point it is assumed that a movable bed river model is to be built and operated. Having assembled all the data required for the study it is necessary to analyse the problem and determine the scope of the experiment.

The boundaries or limits of the model are then drawn upon a small scale map of the vicinity. This calls for careful judgment. To keep the cost of the model within a reasonable figure the extent of river and overbank areas should not be unnecessarily large. Generally speaking, in a river problem the model limits are so selected that the area under examination will be located at or near the middle. The upstream and downstream limits are then fixed so as to give proper entrance and exit conditions. The extent of the overbank area is then determined, the boundaries being selected so as to contain the maximum stages to which the model will be subjected without causing any restriction of flow.

Model Scales.

Having drawn the model limits upon the small scale map, the scale relations of the model should then be selected. The first scales to be decided are those involving the linear dimensions of length and depth or height. In fixing the horizontal scale consideration must be given to the space available for building the model; economy of construction and the degree of accuracy required in the model results. At the Waterways Experiment Station the horizontal scales of most of the movable bed river models have been chosen between the limits of 1: 2,000 and 1: 450.

In fixing the vertical scale the important considerations are that it shall be sufficiently large to ensure turbulent flow, and permit of accurate measurement of water levels as well as changes in the bed and banks of the model channel.

From the horizontal and vertical scales the area, velocity and discharge scales are determined. The last mentioned will indicate the quantity of water required for operating the model. Later on when tests have begun the discharge scale is more accurately determined by measurement at the weir boxes. The difference between the theoretical and actual discharges is usually quite small.

The final slope scale is fixed after careful examination of the results of previous experiments conducted with similar bed material. If simple geometric distortion does not furnish sufficient slope, an additional amount, termed supplementary slope, is supplied by tilting the model.

Model Layout.

The major item in the layout is the plotting of cross sections from which sheet metal templates are afterwards cut and placed in the model. The positions of the templates are first set out on large scale maps, their location and spacing being selected so as to insure that the model will represent the important features of the prototype. The cross sections may then either be plotted on paper or directly upon the galvanized metal sheets. The templates are then accurately cut and mounted upon a wooden frame work to insure rigidity.

A detailed plan of the model is next made and on it are shown the model boundaries, location of the templates and other important features as the weir box, entrance flume, tail gate, discharge flume, model gauges etc.

This plan with the templates are then made over to the construction group who proceed to build the model. This is carried out either indoors or in the open to suit the space and water supply available and other considerations. An area is first cleared to sufficient size, the templates are then carefully set in position and the space between them filled with sand or well tamped earth to within about two or three inches from the top. Fig. 5 shows this work in progress in the Helena-Donaldsonville model.

The final surface upon which topographic details are moulded, is a mortar of Portland cement and sand. The entrance and exit flumes and side walls are then built, the materials used being either brick masonry or concrete.

The measuring weirs are of the Vee notch type, accurately calibrated and installed in rectangular boxes provided with latticed baffles to damp excessive turbulence. Gauges for reading the slopes are either point gauges located over the channel or hook gauges reading in wells connected to the model bed by manometer tubes. The tail gates are either of the hinged or vertical sliding plate type.

In movable bed models the area of the movable bed portion is left in the original model templates as a continuous trough. Into this the bed material is placed and before each run it is moulded to the correct profile by means of suspended male templates laid with their ends resting upon curb rails.

Gauge Relation curves are then plotted from the known water surface slopes of the river. A rating curve is prepared from actual river discharge observations, the model gauges are zeroed and a model hydrograph for verification of the model is then drawn up.

River Model Operation.

Before commencing tests of a movable bed model all the working features are carefully checked, the weir calibrated and gauges set to the required elevations. The movable bed is then moulded to shape and a cross section survey is made from which a contour map is drawn. This map is checked against the corresponding river survey map and should be in close agreement.

Several preliminary runs are made to give the operator an opportunity to check gauge readings, slopes, velocities etc. against the theoretical values obtained while designing the model. In the course of operation some of the bed material is swept out of the model and since in the prototype this moved bed material is replaced by other material brought down from upstream it becomes necessary to make good the loss of bed material from the lower end by adding more at the upper end. The amount to be added naturally depends upon the amount removed from the bed. The material carried through the model is trapped in a recess at the tail end and is measured at the end of each run.

In models operating at variable stages, bed material must be introduced largely at the higher stages since the low stages normally provide insufficient force to move the material off the entrance apron.

Proper verification of a movable bed river model is of the utmost importance; it being reasonable to assume that the more accurately the model is able to reproduce conditions which have occurred in the past, the more accurately will it predict what will happen when the proposed improvement works are installed. The main purpose therefore during the verification period is to make the model simulate as accurately as possible known changes in the bed. To accomplish this a cut and try method is generally adopted.

Two realiable surveys with a sufficient period of time intervening are selected. With the model bed moulded to the earlier survey conditions which actually occurred during the above period are then reproduced. The time scale is then juggled with in the manner already described, the rate of introduction of bed material at the upper end of the model is varied, water slopes may be slightly adjusted, perhaps too, the bed slope. The roughness of the banks and spill areas may be modified and if the results are still disappointing the bed material may as a last resort be changed, till finally conditions are obtained which ensure that the model bed will have approximately the same contours as existed in the river at the time of the second survey. This verification period is often long and tedious but it is obviously useless to proceed further until true reproduction is obtained. When the laboratory is finally satisfied that reliability and accuracy have been established in the model, tets of the proposed works may then begin.

By this time the operator should be thoroughly familiar with the general characteristics of the model, the method of operation, of recording data and the precautions necessary to secure the best results. It is still necessary however that he should constantly observe changes in the model, exercise care and accuracy in recording data and use judgment in interpreting results.

It will probably be necessary to measure velocities in the model. Several methods are in general use. Surface velocities are measured by floats; sub-surface velocities by pitot

tube, by Bentzel tube,—an elaboration of the ordinary pitot tube, or by miniature current meter. The Bentzel tube was developed at Vicksburg and the miniature current meter at the University of Iowa.

Surface current directions are determined by means of wooden floats or confetti. Sub-surface directions are indicated by means of a dye—usually potassium permanganate.

Simultation of the various improvement or corrective works in a model is accomplished in several ways. Permeable dikes are simulated by wire mesh screen and revetment usually by means of gravel.

Overbank features such as trees and undergrowth cannot well be reproduced in the model but additional roughness is applied by means of pebbles or vertical wire mesh bent into concertina shape. Frequently too the entrance apron of the model is roughened by small pieces of stone cemented to the sides and floor to secure proper entrance flow.

When beginning and ending a run it must be seen that undue scour does not occur. It is customery therefore to flood the model at the beginning of the run by admitting water from both ends of the model. Any deep holes are carefully filled from a bucket or hose pipe. Once the flooding is complete the tailgate is gradually lowered and the entrance valve regulated to secure the initial stage.

Similarly the draining of the model requires care. The tailgate is gradually lowered allowing the water to drain off without giving it greatly increased velocity. Pockets and holes are usually drained by means of 1″ rubber hose used as a syphon.

It is common practice to leave outdoor models flooded overnight during the week-ends to prevent damage to the bed by rain. The model is flooded and the valve of the flooding pipe at the tail end of the model is left open just sufficiently to admit water to compensate for leakage at the tailgate.

At Vicksburg special precautions are necessary at those times of the year when the reservoir water contains silt in suspension due to heavy rainfall. It is then necessary to keep the model flooded with water from the city mains to prevent the formation of a thin film of mud over the model bed.

THE U. S. WATERWAYS EXPERIMENT STATION.

Organisation and Personnel.

The U.S. Waterways Experiment Station is the world's largest river laboratory and it may therefore be of interest to mention briefly its organisation, personnel, equipment and the extent of model experimentation undertaken there.

Fig. 12 shows the organisation as it existed in November 1937.

In December 1937 Experiment Section No. 1 had 12 model experiments principally navigation problems in the Mississippi and Ohio Rivers in various stages of progress. Some were being designed, others being constructed, the remainder under test.

Section No. 2 had 5 studies in progress—mainly tidal problems. Section No. 3 was engaged in tests with the Helena-Donaldsonville Model. Section No. 4 had 8 experiments in hand—mainly with structural models.

The personnel of the Hydraulics Division consists of the 5 engineers in charge of sections and 67 assistants nearly half of whom are engineering graduates.

The Construction and Maintenance Section consists of the Engineer-in-charge and 27 assistants.

The Soils Division is under the charge of a Soils Engineer with four assistants in charge of the Soil Research Centre, two Testing Sections and the Technical Section, and 12 others.

The unskilled labour permanently employed at the Station consists of 18 white and 63 negro labourers. Most of these are engaged under the Construction and Maintenance Section.

Expansion of the Experiment Station.

When opened in 1931 the Waterways Experiment Station had been planned upon quite generous lines but it was not long before it became apparent that the laboratory space and water supply were quite inadequate. To make room for new models it became necessary to break up old models almost immediately

after completion of their tests. This policy was however discontinued when it was found that susbsequent tests were not infrequently required. To-day models are usually retained till it is fairly certain that they will not be required any further.

The eight acres of land acquired in 1931 was fully occupied by models by 1934. Water storage became so acute that in 1933 it became necessary to raise the crest of Brown Lake spillway by 3 feet to increase the storage capacity from 255 to 440 acre-feet. In 1934 a combination pump-fed constant head tank system was installed increasing the discharge of the circulating system by 10 cusecs.

The same year a further 35 acres of land were acquired, 18·6 acres of which could be utilised for model construction. This area was split up into Experiment Fields Nos. 3, 4 and 5. With the Laboratory now firmly established it was felt that its future development should be properly planned, particular attention being paid to water requirements. Allowing a 75% load factor it was decided that 10 cusecs discharge and 9,000 cub. ft. storage per acre of usable model land would be needed for the new experiment fields. This additional 186 cusecs would be supplied from a supplementary high level reservoir through 5 constant head tanks by two pumping stations having capacity of 85 and 95 cusecs respectively. An earthen dam was built by the Soils Division and a small booster pumping station installed on the edge of Brown Lake in order to maintain storage in the new reservoir.

The pumping stations will eventually be equipped with units of 5, 10, 15, 20, 35 and 5, 10, 20, 25, 35 cusecs capacity. To begin with the two smallest pumps were installed in each station, while the remainder are being supplied to keep pace with the development of the new fields. Thus splitting up the total discharge into the units selected will result in considerable economy. With fewer and larger pumps, considerable wastage would have occurred if only one or two models were in operation at one time.

In developing a large river laboratory it is essential to plan well ahead for it is certain that space and water requirements will rapidly increase. The early hand to mouth expansion just described was unavoidable since the Experiment Station was

inaugurated with very little enthusiasm and backing and it was some time before the authorities awoke to realisation of its possibilities.

During the time the author was at Vicksburg he was impressed not only by the keen spirit of co-operation pervading the entire personnel and the thoroughness with which experiments were undertaken but also by the rapidly growing respect which the work of the laboratory now commands amongst practical river engineers.

A noteworthy feature of the Waterways Experiment Station, the Bureau of Reclamation hydraulic laboratories, the Iowa Institute of Hydraulic Research, and in fact every important hydraulic laboratory in the U.S.A. is that they are directed and staffed by hydraulic engineers.

The Director and Assistant Director of the Waterways Experiment Station are officers of the U.S. Corps of Engineers who have been engaged in river and harbour work for the greater part of their service. In addition to having taken the usual post graduate course in hydraulic engineering it is customary for them to have undergone special hydraulic laboratory training either in the U.S.A. or Germany or generally in both.

The leaders of sections in the Hydraulics Division are civilian engineers of the U.S. Engineer Department who have been engaged in practical river and harbour engineering then given special training and drafted to the laboratory. Many of their assistants have undergone similar training.

Hydraulic Model Experimentation in India.

India at present possesses two large hydraulic Experiment Stations, the Central Irrigation and Hydrodynamic Research Station at Khadakvasla, near Poona and the Punjab Irrigation Research Institute at Lahore. In addition there are two small stations at Karachi and Lucknow.

During the period 1928-1935 numerous model experiments dealing principally with irrigation structures were conducted at Poona under the direction of Mr. C. C. Inglis, C.I.E., M. Inst. C.E., then Superintending Engineer, Irrigation Development and Research Circle, Government of Bombay.

In 1935 the scope of experimentation was broadened to include river models and during that year important experiments connected with the protection of the Hardinge Bridge at Sara, Bengal were commenced. Since April 1st 1937 the Station has been financed by the Government of India with Mr. Inglis as Director.

During the last three years the experiments carried out to safeguard the Hardinge Bridge have yielded valuable information. The main model, reproducing the Ganges for a distance 19 miles upstream and 8 miles downstream of the bridge, has recently been extended to include to a further 19 miles of river upstream and 8 miles downstream of Sara. Its overall length now becomes 550 feet making it by far the largest river model yet built in India.

Further experiments are now being conducted with the object of ascertaining what changes in the course of the river are likely to occur in the next few years. This will be a most complex study involving amongst other things, the problem of river tortuosity as affected by silt charge, slope, artificial obstructions and other factors.

Another very important experiment now being undertaken at Poona has for its object the prevention of silt deposits in the right bank canals at Sukkur Barrage. A large model of the Indus has already been operated for some time and an even larger one to carry approximately 30 cusecs is contemplated. This discharge is several times that of the largest movable bed model built at Vicksburg.

Other river model experiments recently carried out at Poona include the following —

Training the River Mula above the Rahuri Causeway; the Sina River at Mile 5 of the Ahmednagar Manmad Road; the Sarda River above the barrage at Banbassa, United Provinces; the Jumna River at New Delhi and the River Watrak in Gujerat.

Besides river model studies, the Central Irrigation and Hydrodynamic Research Station is regularly conducting experiments with structural models such as, headworks sluices, standing wave flumes, spillways, canal falls etc.

A notable feature in the design of river models at Poona has been the complete adoption of model scales based upon Lacey's[1] theory, apparently with excellent results. His formulae are an invaluable contribution to hydraulic model experimentation since they now enable vertical distortion of river and tidal models to be placed upon a rational basis instead of requiring one to rely almost entirely upon purely arbitrary assumptions.

It seems safe to predict that before long, the other hydraulic laboratories engaged in the solution of alluvial river problems will be employing Lacey's formulae.

They clearly indicate that movable section river models should have a much greater discharge than has hitherto been considered sufficient. This unfortunately means a considerable increase in the cost of the experiment.

The Punjab Irrigation Research Institute was established during 1925 to investigate the alarming rise of water table and consequent extension of the waterlogged areas in that province. Since then however its activities have extended considerably under the guidance of Dr. McKenzie-Taylor, and to-day it comprises an extremely well equipped laboratory at Lahore and a field laboratory at Malikpur.

The Institute now consists of the following sections—Chemical, Physical, Mathematical, Hydraulic, Statistical, Land Reclamation and General. In the Hydraulic Section extensive use has been made of models for improving the design of Irrigation structures, a large number of weir sections having been tested in the flume to devise means for reducing scour downstream. Canal falls of various types have also been built to comparatively large scale at Malikpur and have recently been undergoing tests.

Two river model studies have lately begun. The larger model constructed at Malikpur and reproducing the Chenab and Jhelum rivers at the site of the proposed Trimmu Weir;

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(1) References:—Stable Channels in Alluvium by Gerald Lacey, B. Sc., M. Inst. C. E. Paper No. 4736 Proc. Inst. C. E. 1930. Uniform Flow in Alluvial Rivers & Canals by Gerald Lacey Paper No. 4893 Proc. Inst. C. E. 1933.
Government of Bombay Technical Paper No. 46 Appendix I.

the second model reproducing the Sutlej River at the Islam Weir site and built to determine means of removing a bela which has formed on the right bank immediately usptream of the weir.

A most notable contribution of the Punjab Irrigation Research Institute has been its work in connection with sub-soil flow and uplift pressures under irrigation headworks.

The recent Central Board of Irrigation publication No. 12 "Design of Weirs on Permeable Foundations" by Rai Bahadur A. N. Khosla, Drs. Bose and McKenzie-Taylor marks a very considerable advance upon our previous knowledge of this important subject. Needless to say, extensive use has been made of models during the course of the investigations.

From the foregoing remarks it will be seen that the work of the Punjab Irrigation Research Institute has been almost entirely directed to the solution of problems relating to Irrigation.

At Lucknow and Karachi no river model studies have yet been undertaken, the experimental work having been exclusively devoted to irrigation matters.

The position therefore in India at the present time is that the major Irrigation provinces have been quick to realise the usefulness of hydraulic model experimentation and have already obtained valuable results. Their experiments have however been almost exclusively directed to the study of the flow of water over, through and beneath irrigation structures and only at Poona can it really be said that river improvement problems are being seriously investigated by means of models.

When one considers the vast number of river training and flood control problems which await solution in Bengal alone it is evident that increased facilities for river model experimentation are urgently needed.

With the establishment of the proposed new Central Irrigation and Hydrodynamic Research Institute it is expected that these facilities will become available and that tidal as well as inland river model experiments will then be undertaken upon an extensive scale.

Of the tidal problems in Bengal, one of the most important is the determination of suitable means for improving navigable depths in the River Hooghly. Hitherto the Calcutta Port Commissioners have relied entirely upon dredging for the maintenance of the navigation channel, but with present annual dredging costs in the region of Rs. 11 lakhs and still mounting, it is evident that permanent training works in the lower river should now be seriously considered.

The only possible method of determining at reasonable cost the most suitable location for these works is by a properly designed tidal model.

It is stated that the Hooghly headwater supply from the Ganges has appreciably diminished during the last twenty-five years. Means for increasing the channel capacity and discharge of the Nadia river off-takes could likewise be profitably investigated by means of models.

Of the countless inland river problems awaiting solution, the most urgent are the resuscitation of the dying rivers in Central Bengal, the control of the Damodar River floods and the prevention of destruction by erosion of important reverside towns.

In his Annual Address delivered to the National Institute of Sciences of India in Calcutta at the beginning of 1938 Professor M. N. Saha dwelt at length upon the problem of India's rivers, particularly those of Bengal, Bihar and Orissa. He urged that regional river physics laboratories should be established without delay ; further that these laboratories should be staffed by pure Scientists. This latter proposal if adopted would be in striking contrast to the practice prevailing in America.

In river and tidal model experimentation, success depends so largely upon one's ability to read indications correctly and supplement the usually inadequate data by a practical knowledge of the behaviour of rivers, that without this knowledge the experimenter must be at a most decided disadvantage. There is always the danger too of training works being tested in the

model which must obviously be doomed to failure in the prototype. For example much time and labour, and incidentally expense, may be wasted on simulating a cut-off which in nature could not possibly maintain itself.

It is most important that engineers in the field should have confidence in what is being undertaken in the laboratory. This confidence is now plainly visible in the U.S.A.

In capable hands, a river hydraulics laboratory undoubtedly provides the best known approach to the solution of river improvement and flood control problems. While freely admitting that river models possess decided limitations, as will be gathered from what has been said earlier in the paper, nevertheless without them the solution of complex problems would in most cases be impossible except by repeated trial and error methods involving enormous expenditure.

Given reliable data with which to design and operate the models, the necessary laboratory equipment, suitable and sufficient water supply and lastly trained engineering staff, there is no reason why India should not derive the same extent of benefit from river model experimentation as is being obtained in America.

The prosperity of Bengal in particular is inextricably bound up in her river system and neglect of these waterways must inevitably result in further agricultural deterioration and with it the increased ravages of malaria.

Acknowledgment.

The author desires to acknowledge his very great indebtedness to the Director and Staff of the U.S. Waterways Experiment Station, the Associate Director and Staff of the Iowa Institute of Hydraulic Research, and Officers of the U.S. Engineer Department and Bureau of Reclamation for their unfailing courtesy and invaluable help during his stay in the U.S.A.

ACTIVITIES OF LOCAL CENTRES.

A General Meeting of the Institution of Engineers (India), Bombay Centre was held on Friday, 25th August 1939 at 6-15 p.m. (S.T.) in the Institution Room to hold a discussion on the subject of "Reinforced Concrete Construction in Bombay."

In the absence of the Chairman, Mr. N. V. Modak was duly proposed to the Chair.

25 members and 18 guests were present.

Mr. N. V. Modak in opening the discussion invited all young Engineers to give their views and suggestions so that he could take them into consideration in the R.C.C. Code that was proposed to be prepared for the town of Bombay.

Mr. J. M. Darukhanawala said that the Reinforced Concrete was a good servant but a bad master and emphasized the desirability of proper control by the Supervisor, Architect, R.C.C. Specialist and lastly by the Municipality. He then dealt with the difficulty of knowing the exact source of materials, allowable stresses and expressed that the R.C.C. Work in Bombay at present was very discouraging and required improvements in all directions. He recommended a code on the lines of the L.C.C.

Mr. K. J. Mhatre was of opinion that there was at present no scientific basis in the manufacture and selection of materials like crushed stones, sand etc. as regards shape, impurities, grading and strength. He was surprised to have detected sugar contents in water. He then explained the position of the Specialist contractor who was compelled to give cheap work because of the competition. He then dealt with the relation between the R.C.C. Specialist on one hand and the owner, the Architect or the Contractor on the other.

As regards design he found that many Engineers failed to notice the monolithic character of R.C.C. Construction. He advocated the deflection methods of design and thought that slabs should be designed as plates. He complained against the Municipal Engineers who did not recognize the distinction between the interior and exterior columns—the former taking mere load and the latter mere tension. He thought that an R.C.C. Specialist must in the first instance be a sound structural Engineer.

Mr. B. R. S. Iyengar had no complaint against the design. He however found difficulty in getting reliable standard material —such as steel and unadulterated cement. In his opinion there was very great scope for improvement in workmanship. He advocated licensing of Specialists and Contractors and testing work in progress.

Mr. A. N. Patel thought that there was bound to be some difference in stone and sand obtained from diffierent sources. He explained the three types of crushers and said that the shape of the aggregate could be controlled by the choice of the type of crusher.

Mr. S. B. Joshi agreed with Mr. Mhatre that the R.C.C. Specialist must be a sound Structural Engineer. He said that one could learn of R.C.C. more by testing R.C.C. Work to failure than by reading books. He was of opinion that ordinary slabs were stronger than beams and advocated modern methods in the design of slabs. He then stressed the importance of bond stress and said that allowable steel stress should depend upon the quality of the concrete. He emphasized the importance of well-washed aggregate.

Mr. N. H. Mohile said that the London County Council had three classes for concrete construction, *viz.* (1) Ordinary concrete, where no supervisor would be required, (2) High grade and (3) Special grade. He further said that supervisors and others in charge should be men certified by municipalities and local authorities for such work. In his opinion the employment of specialists by contractors was a bad system which should be discountinued as soon as possible. He regretted that contractors and others in charge did not take advice from a disinterested

person. He said that instead of mixing cement according to measurement it should be mixed according to weight. Pamphlets issued by the Concrete Association of India were not meant for Architects who could get help of specialists, but for those who could not get services of specialists.

The President said that the authorities did not check the designs minutely as they trusted the R.C.C. Specialists to know their responsibility. He further said that the municipality was contemplating licensing the supervisors and specialists in R.C.C. In conclusion he thanked those who took part in the discussion and hoped that more would give the benefit of their experience at a later meeting.

The meeting terminated with a vote of thanks to the Chair.

A General Meeting of the Institution of Engineers (India), Bombay Centre was held on Friday 5th January 1940 at 6-15 p.m. (S.T.) in the Institution Room to hold a further discussion on the subject of "Reinforced Concrete Construction in Bombay."

Mr. J. D. Daruvala, Chairman, occupied the Chair.

42 members and 30 guests were present.

The Hon. Secretary read the minutes of proceedings of the previous meeting held on 25th August 1939 to discuss the subject of "Reninforced Concrete Construction in Bombay."

(Mr. D.N. Jayakar spoke at the previous meeting, a summary of his remarks is being included in the proceedings of this meeting).

Mr. Jayakar considered the subject under the following 11 heads :—

(1) Cement, (2) Metal, (3) Sand, (4) Steel, (5) Centering, (6) Labour Gangs, (7) Architects, (8) Consulting Engineer, (9) Contractor, (10) Owner and (11) Municipal Authority.

(1) Cement—Mr. Jayakar observed that the control of the sale of cement was in the hands of the Cement Marketing Co., and very small margin of profit was left to the Distributing Agents. This in his opinion was the main cause of adulteration of cement. He then described how the adulteration of

cement was going on, on a large scale and how empty cement bags were in great demand. He wondered why the Cement Marketing Co., and the Bombay City police did not look into the matter.

(2). *Metal.*—He observed that the Void test showed that the metal available in Bombay was not of proper quality. Metal sold at cheaper rates was always adulterated with metal crushed from rubble from a rejected quarry. The shape of the metal available was also not cubical.

(3). *Sand.*—In his opinion the Mumbra sand was good but it required a good deal of washing. The Bhyander sand was salty and therefore injurious to the R.C. work but it being cheaper was in great demand with the builders who wanted every thing cheap.

(4). *Steel.*—Mr. Jayakar warned the Engineers against using local steel manufactured at Wadala. He said that it was brittle and on bending was found to be laminated, granular and uneven.

(5). *Centering.*—He said that due to the craze for cheapness motor-car packing boxes were generally used for centering. It was his opinion that centering should be considered as an important item by responsible Engineers.

(6). *Labour Gangs.*—He said that many of the Labour Gangs had become very unruly and would not listen to the Supervising Architect or the Mistry or the Contractor or the Owner. They would always have their own way. Thus they would decide the water-cement ratio to suit their own convenience. They would not care if the steel was displaced by their moving about.

(7). *Architects.*—Mr. Jayakar had a very poor opinion of the knowledge the Architects possesed of the R.C. work. He was of opinion that it was time the Architects stopped designing the R.C. work by the "Thumb Rule" methods.

(8). *Consulting Engineer.*—Due to want of etiquette anybody in Bombay could style himself as "Consulting Engineer". Mr. Jayakar endorsed the suggestion of enforcing the Consulting Engineer on every job.

(9). *Contractor.*—Mr. Jayakar thought that the profession of Contractors was not properly organized. Anybody, without any technical knowldege of the work, could term himself a "Contractor" if he had a few thousand rupees to his credit in a bank. He proposed that services of a qualified Contractor must be enforced with a view to efficiency.

(10). *Owner.*—The Owner was a layman at the mercy of the Architect or the Engineer but if he insisted on every letter of law in the agreement, better quality of work could be turned out.

(11). *Municipal Authority.*—Mr. Jayakar thought that the staff of the Municipality was quite insufficient to go through the calculations submitted by R.C.C. Specialists, with the result that the calculations were not properly scrutinised. Due to the lack of Municipal control faulty designs were becoming fashionable and it was found to be difficult to convince the Architect on a new rational design.

With all these difficulties Mr. Jayakar thought that the R.C.C. work carried out in Bombay was on conservative lines. The building boom was due firstly to the fall in the bank rate of interest and secondly to the introduction of the R.C. construction on large scale. Much would depend, therefore, on the status that would be granted to the Consulting Engineer in the revised Bye-Laws.

Mr. M. G. Cervello wanted to know whether the Municipality wanted detailed working drawings and calculations for every member of the building or whether the Municipal Offices would be satisfied with a typical calculation of say one beam, one column, one footing etc. He was of opinion that the remuneration of the R.C.C. Specialist should, in every case, be paid by the Owner of the building and be invited the Institution of Engineers (India) to look into the matter.

Mr. M. K. Surveyor spoke from the point of view of a Building Contractor with the personal experience of 25 years at his back. He had found that whenever anything went wrong, the Building Contractor was invariably blamed. He stated a case where a concrete slab did not sufficiently set due to intense cold and where the Contractor was accused of using less cement. It was later found that after curing the concrete with warm water it took its usual strength and the Contractor was un-

necessarily blamed. He said that till recently the Contractors were unqualified persons and naturally submitted to the dictates of the Architect whether the latter was right or wrong. He then criticized the attitude of the Owner and the Architect towards the Contractor. He found that the Architect by hook or crook induced the Owner to construct a building and harassed the Contractor by taking resort to one-sided conditions of the contract. Mr. Surveyor then showed how the percentage tenders drawn up by the Architects were, in many cases, most inequitable and unworkable. He also stated instances where the Architects varied their designs according to the person who employed them. Thus the design of the Architect would be different according to whether he was employed by the Owner or by the Contractor. He knew of instances where the Architects never cared to look into the question of shuttering which they thought was the Contractor's affair. He criticized the stipulation in the contract whereby the Contractor was required to pay the R.C. Designer's charges.

With regard to Mr. Mhatre's suggestion to make specifications very strict, Mr. Surveyor warned the Engineers to be practical. He was of opinion that 'T' beams were not always economical and practicable.

With regard to Mr. Mhatre's suggestion of designing slabs as thin plates Mr. Surveyor found that many R.C.C. Specialists used moment reduction factors as load reduction factors in computting the load transmitted from the slab to the beam. This was of course wrong. He thought that No. 1 metal could be replaced, with advantage, by shingle which gave better crushing strength and denser concrete than one of all stone crushed and screened. He had no difficulty in having his designs approved by the Municipal Authorities and did not agree with the accusation that Municipal Inspectors were incapable of understanding the finer points of the designs.

Mr. Surveyor recommended adoption of the L.C.C. regulations for the new revised Bye-Laws of the Bombay Municipality. He thought that the minimum stress recommended by the L.C.C. should be considered as quite safe. He was, however, of opinion that the Bye-Laws should be sufficiently elastic to enable better Designers and Contractors in exceptional cases of need to put up economical structures.

Mr. J. M. Darukhanawala was generally disappointed with the present day methods of construction and workmenship in Bombay and was, therefore, of opinion that Engineers should generally be conservative in the matter of construction on concrete and steel. He was not enthusiastic about new stress recommended by the L.C.C. being adopted in Bombay and opined that 600 lbs./sq. in should be the compressive strength. He was not sure whether concrete which went by the name of 1 : 2: 4 was really 1 : 2 : 4. With regard to steel he said that he had tested some sample bars and found that the working stress that could be allowed was only 14,000 lbs./sq. in. and that he was not prepared to recognise the stress of 18,000 lbs./sq. in. for steel. He would rather stick to 16,000 lbs./sq. in. In case of columns he was of opinion that $1\frac{1}{2}''$ cover outside should not be allowed in calculating the sectional area of the column as was done by the old regulations. He explained that his views were in view of conditions prevailing in Bombay.

Mr. B. R. S. Iyengar found that the calculations submitted to the Municipality were a matter of formality. As the R.C.C. Specialists were responsible for the R.C. work, he thought that some kind of control was necessary on the Specialists. He deprecated the way some of the Architects passed materials rejected by the Specialists without referring to them. He was of opinion that the Owner should appoint the R.C.C. Specialist. He commended the idea of lisencing the R.C.C. Specialists, R.C.C. Contractors and R.C.C. Supervisors. He was in favour of higher stress being allowed if the work was entrusted to a responsible person.

Mr. S. B. Joshi expressed that there was unanimity of opinion that some improvements were necessary in R.C. construction in Bombay. The improvements were partly administrative and partly technical. As regards administrative improvemnets there was the suggestion of lisencing the R.C.C. Specialists, and Contractors. A Committee should be appointed to go through the pros and cons of the question. As regards technical improvements Mr. Joshi thought that when three grades of concrete recommended by L.C.C. were adopted, a testing machine for testing 6″ cube of concrete would be required. He suggested that the Municipality should purchase such a machine. In the alternative Mr. Joshi suggested testing quality of concrete by 'Tension' test. He also suggested the 'Deflection' test for

examining the quality of R.C. work. He was in favour of high stress if the concreting was done under proper supervision. He then expressed that there was generally a misunderstanding of the term 'Factor of Safety' which, according to him, did not include any margin of safety. He thought that reinforced concrete being a composite structure no Contractor could give a rate for R.C. construction as he would in the case of ordinary steel. He suggested that reinforced concrete should be paid under three different items namely, Steel, Concrete and Form work. He did not agree with Mr. Darukhanawala's suggestion of sticking to old stress. He pointed out that even the Indian Roads Congress had adopted the stress recommended by the L.C.C.

Mr. M. G. Cervello had no objection to the use of shingle as aggregate provided it was well graded and free from dust. He had found Mumbra sand free from dust. He recommended that the Supervising Engineer should supervise the centering work. He did not agree with Mr. Darukhanawala as regards L.C.C. regulations and was of opinion that new regulations should be adopted. He found that Tata Steel could be favourably compared with the best English steel. He did not agree with the opinion that the quality of work in Bombay was poor, and expressed the opinion, on the strength of his 40 years' experience, that the quality of work in Bombay could be compared favourably with the best work of its kind in Europe and America.

Mr. Burjor S. J. Aga agreed with Mr. Cervello in that the steel work was being properly prepared by efficient workmen but that the reinforced concrete work that was generally carried out in Bombay was far from satisfactory. Instead of putting in the requisite quantity of water, as a rule more water was used with a view to make the mixture easily workable, ignoring thereby the strength of the concrete that would be impaired. With high buildings, instead of mechanical contrivance to raise the concrete, the usual working was to have the mixer on the ground floor and take the concrete on the top stories by manual labour. Shingle when used was not properly sorted with the result that the shells and other undesirable matter also went in. It was necessary to treat the balcony slabs and parapets as well as weather sheds and aprons with a richer mixture of concrete or with cement concrete and plaster with waterproofing materials

in them. This was also necessary for W.Cs and *nahnis*. The density of the concrete in a place like Bombay, where climate conditions and humidity in the atmosphere differred to a great deal from upcountry, was of considerable importance in order to safeguard against detrimental effects due to the rusting of the steel especially in exposed situation and proximity of the sea. Careful attention should also be given to the jumbling of bars in beams over columns. It was a question whether the sand and gravel, at times used indiscriminately in Bombay, started any chemical action in reinforced concrete work.

Mr. N. V. Modak thanked the members for the keen interest they had taken in the discussion and invited them to give the benefit of their experience in the formation of the new R.C.C. regulations for the City of Bombay.

The President thanked the members for having taken part in the discussion and suggested that a Committee be appointed for assisting the Municipality in the formation of the new R.C.C. regulations.

The meeting terminated with a vote of thanks to the Chair.

THE ENGINEER AND HIS WORK IN INDIA

Speech by Sir M. Visvesvaraya at the Annual Dinner of the Institution of Engineers, Bombay Centre, November 20, 1939.

Mr. Chairman, Ladies and Gentlemen,

I esteem it a privilege to be invited to meet the members of this Institution and take part in your annual convivial gathering. Before I proceed to make the observations, I have in view, I wish to thank the Chairman for the kind things he has said of me in presenting the toast of the guests, and you, ladies and gentlemen, for the friendly manner in which you have received it.

Meetings and conferences on matters of interest to the engineer being rare in this country, there is, I understand, much appreciation on the part of the members of the profession of the good work that is being done by this Institution. It provides a forum for the active discussion of all professional matters calculated to advance "the science, practice and business of engineering in India." Social gatherings associated with the Institution also afford members further mutual profit and pleasure.

The Engineer, whether in the service of Government, a Municipal Corporation or a large industrial undertaking, does his work unobserved. He may inspire but cannot shape policies. In the course of his daily routine he usually does a vast amount of designing and constructional work, standing behind a ruler, administrator, financier, or business syndicate. The majority of engineers in this country have no independent status. They are something of a drudge in the national household. They are not accustomed to discuss national affairs in relation to their profession, nor even to tender advice as a body on matters in which their views materially affect the interests of the State.

In a wider sphere the engineer is a link between the true scientist, the inventor and the public. Recent revolutionary discoveries in science have resulted among other things in

improvements in production of commodities, and phenomenal developments in communications. For many of these improvements and developments and for the present high standards of living in Western countries, the engineer is responsible to a large extent. It is he that coverts the discoveries of the scientist and inventor into goods and services, into practical utilities for the convenience of man. This kind of work has been going on with bewildering rapidity within the past 30 or 40 years. As a result, the engineer is specialising, his work is being divided and sub-divided and it is growing both in volume and variety. There never was a timc when the services of the engineering profession were more needed or were more important than they are to-day.

CLASSES OF ENGINEERS

In former times, only two classes of engineers were recognised, namely, the "civil" engineer and the "military" engineer. As the present time too, there are two main divisions (1) the civil engineer, and (2) the mechanical and the electrical engineer. The former class is associated with civil works, such as, roads, bridges, irrigation works, public utilities and city engineering works, and the latter with workshops, railways and other transport agencies, but mainly with industries and their equipment and operation.

Specialisation is going on in various trades in which engineering plays a part. For example, there is the mining engineer, metallurgical engineer, power engineer, locomotive engineer, radio engineer and so on. There is another class of professional men, who assume the appellation, like the chemical engineer, the sales engineer and others whose allegiance to the engineering profession can only be regarded as secondary or partial.

PROGRESS OF ENGINEERING WORKS

Almost all important engineering works of modern design in this country, such as, large bridges, railways, port and harbour works, owe their origin to the foresight and initiative of British Engineers. Some few are old works improved and adapted to modern standards.

There are some 42,000 miles of railways but in recent years progress in railway work has been very slow. The institution of petrol tax fund marks an important development in road

policy. In the field of irrigation, some notable works have come into existence during the past five and twenty years. The Sukkur Barrage Works in Sind, the Mettur and Krishnarajasagara reservoirs on the Cauvery, the Nizam Sagar in Hyderabad and the Lloyd Dam in the Province of Bombay are examples of some of the largest works of this class in any part of the world. There are great canal schemes in operation like the Sutlej Valley Works in the Punjab, the Ganges Canal Works in the United Provinces and other similar ones in Madras and Sind. On the whole works of hydraulic engineering have made great advance under British rule in India.

A few hydro-electric works have been established in Bombay, Mysore, Madras and recently in the United Provinces, but they are on a small scale when considered in relation to the size of the country.

In the principal cities and towns there has been some progress in water supply, drainage and electric light and power supply works. The water supply projects of Bangalore, Indore and Gwalior, for instance, and the sewerage schemes of Delhi and Hyderabad (Deccan) are among the more important works of this class. City planning and public buildings of architectural importance have lagged behind. Progress in all these classes of works has been haphazard. If town planning of New Delhi and rebuilding of Quetta and extensions in Bombay be omitted, there is as far as I am aware no house building project or programme on a large scale anywhere. Urban areas are on the whole ill-served. One reason for this is the poverty of their resources and another the lack of any plan or nation-wide scheme of development.

The branch of the profession in which progress is least noticeable is industrial engineering. Neither large-scale nor cottage industries can be said to have made any satisfactory beginning as yet. Steel, sugar, cement, match, paper and a few other industries have come into existence in recent times, but if regard be had to the magnitude of the country or the human interests involved, the volume of products and number of workers employed are as yet negligible. Shipbuilding has scarcely started yet; neither have power machinery, automobiles, aeroplanes or armament manufacture.

ENGINEERING EDUCATION

Turning to education, there are eight or nine engineering colleges in India, most of which give instruction in the civil engineering branch of the profession. Comparatively little attention is paid to the mechanical and electrical side which is so essential for industries and the manufacture of machinery of defence. In the colleges where those subjects are taught, admissions are strictly limited. A recent investigation showed that the number of young men under training for these two branches of the profession was only 75 or 100 for a part of India peopled by some 60 million souls.

As far as I am aware, other special subjects such as military engineering, automotive engineering, aeronautical engineering, marine engineering, shipbuilding, and the like, are not taught anywhere. Armaments, munitions and weapons of defence remain a sealed book to the Indian student.

The average Indian engineer does not lack energy or capacity, a good many have ability and engineering skill of a high order, but what they need guidance in is capacity to work in harmony with other people, discipline, unselfishness and accuracy of thought and expression.

Many students go to foreign countries although the right thing for them to do is to receive all the education they can get in Indian Universities and go to foreign lands only to obtain training in such specialised subjects as applied science and industries for which provisions in this country is meagre.

It is said that America gets on without very much technical education. In America, however, where there is opportunity for all, ability is quickly recognised even in humbler positions. There are many instances of persons in that country, who started as workmen or office boys, rising to leadership in industries by educating and training themselves, by learning while working. Such opportunities for the poor are rare in this country.

ENGINEERING BOOKS AND PERIODICALS

The publication of books of up-to-date value and interest in various branches of engineering is another matter which requires the serious attention by a body like this. Engineering

literature produced locally is of the scantiest kind. Some valuable text books in civil engineering were originally compiled under Government auspices by professors of the Roorkee College of Engineering. Some other engineers of the Public Works Department and Professors of the Colleges of Engineering have written a few more books, but there is no plan, no attempt among engineers as a body, to advance engineering literature for the benefit of the students or the engineers in practice.

It is not every engineer that can write a book and Indian engineers have had no practice to work in collaboration. Many eminent English engineers have developed productive and other public works by their ability and devotion to duty. Among Indians we have had some outstanding engineers like the late Sir Lala Gangaram, Sir Rajendranath Mookerjee and others. In the Province of Bombay, men like the late Mr. W. L. Cameron, Mr. Hill and Mr. Beal have rendered yeomen service in recent years, and among Indians of the same class who have left and excellent record should be mentioned Mr. Taraporewala, Mr. K. G. Desai, Dewan Bhahadur K. R. Godbole, and Mr. Ibrahim Ahmadi.

Either Government or a body like the Institution of Engineers should make a special effort to select suitable men to write books in various branches of engineering. Some books may be written by collaboration. It is important that prizes or money grants should be available either from Government sources or by raising a public fund to encourage authors. If, however, no action is taken now and matters are allowed to drift in this respect, if no one cares and no one works, the conditions will be no better ten or even twenty years hence.

Engineering journals too are few and inadequate. There are two journals doing good work on the Calcutta side. Considering the vastness of the country there is scope for the publication of a journal of a high standard like the "Engineering" or the "Engineering News-Record". There is no lack of engineering schemes of great value to the engineer projected or constructed in the country, but reports of many of them lie buried in the records of Government and out of reach of the ordinary college student or the practising engineer.

EMPLOYMENT FOR ENGINEERS

There are many schemes in municipal areas generally which require expert engineering advice and also many Indian States which want technical advice and guidance in engineering matters. For lack of such guidance, it takes many years for a town-planning or water supply scheme or a bridge or a canal project to take shape. Mistakes are often made in execution and money wasted. At the same time, there are competent engineers chiefly among the retired officers of Government who would be glad to render help both in design and during construction. At present there is no agency which takes the responsibility to utilise engineering talent to the best advantage. There is, therefore, need for a central agency, either Governmental or private, to which works which require technical advice may appeal for help and engineers who would be glad to get employment might notify their willingness to be consulted or employed. If the Central Agency is not to be a Government body, a firm of Consulting Engineers may be started for civil engineering works. Such a firm, if established in Bombay or Delhi, might be very helpful. If administered on business lines, it should become self-supporting in the ordinary course of three or four years' time and it would easily repay the initial expenses of its establishment.

EMPLOYMENT FOR INDUSTRIAL ENGINEERS

There is at the present time great enthusiasm in the public mind for development of industries. The Congress authorities have been stressing the importance of minor and cottage industries. The Central Government has given a grant for the same. What the country needs is industrial undertakings of all grades—large-scale, medium-scale and cottage—particularly large-scale and key industries. It is with the help of key industries that substantial progress in mechanical arts and machinery can be secured. The heavy industries act as a balance wheel in all mechanical activities in the country's economy. Here I must frankly state my conviction—and I shall have in doing so the support of all who have seen and studied industrial life in advanced countries—that the Indian popular leaders who are indifferent or opposed to this class of industries will be retarding progress and preventing the country from emerging from the position of a primitive state.

In the case of industrial engineering also, a firm of consulting engineers—mechanical and electrical—if started in Bombay or Delhi would be a valuable support to industrial enterprise at the present juncture. It should be controlled by a Board of Management with a small premanent staff but it should have on its register the names of all outstanding men in the professions whether employed under Government or in private undertakings, who could be consulted on important industrial schemes. Such a firm too would be a good investment to those who initiate it.

It would be a national gain if a leading firm like Messrs. Tata Sons, Ltd., or Messrs. Nowrosjee Wadia & Sons with which Sir Ness Wadia is associated, started a firm of Consulting Engineers to help industrial undertakings and works requiring advice from mechanical or electrical engineers.

I notice that Mr. E. J. B. Greenwood, in his last Presidential Address delivered in Benares, is strongly in favour of setting up large-scale industries. Without decrying them altogether he rightly holds that the economic value of cottage industries to the state is comparatively minor.

EXISTING DISABILITIES

Our greatest hope of creating new opportunities for employment and raising the income of the masses lies with industry. The position of the British Provinces is weak industrially because there is no plan, no purpose, no organisation to guide them. The annual Industrial Conferences convened by the Government of India content themselves with talks on hand-weaving of cotton or woollen goods and other minor matters. They have, judging from the reports, never introduced a single heavy industry or a single measure calculated to promote real industrial progress. Such conferences in a country hungry for industries is a mockery. If any Engineer present thinks I have undervalued the work done by these official Conferences, he has only to read the proceedings to satisfy himself.

Government policies have for a long time been unfavourable to industrial growth. I can give instances from my own personal knowledge. About the year 1910, the Government of Madras organised an Industries Department and put a competent Industrial Engineer, Mr. (afterwards Sir Alfred) Chatterton

at its head. Lord Morley, the then Secretary of State, promptly ordered that the expenses of the Department should be curtailed and industries should be left to private enterprise. I was then in office in Mysore and the Government of Mysore on my advice took over the services of Mr. Chatterton who was not wanted in Madras. I had the pleasure of working with that able Engineer for nearly seven years and the present-prosperous sandalwood oil industry in the Mysore State is due entirely to his efforts.

You must have noticed that freedom to develop industries has been weaker in the British Provinces than in Indian States. Mysore, for instance, has had a freer hand since 1910, and as the present Dewan of Mysore has claimed, with justifiable pride, in his recent pronouncements, there has been a substantial growth in revenue and income as a rssult of active public works and industrial policies in that State.

Industries started by private individuals or companies in this country have often met with disaster. When a private industry is in distress, neither Government nor banks nor businessmen go to its rescue, as they do, for instance to my personal knowledge, in an industrial city like Osaka in Japan. This unfortunate tradition has persisted far too long.

India's position industrially is weak because industrial engineers are not trained in sufficient numbers, tariff policies are half-hearted, banking facilities inadequate, and transport organisations like railways, shipping, etc., are in the hands of agencies not interested in industrial progress. Public works, industries and even nation-building activities grow and thrive on public loans. Many countries have prospered in this way but there has been no attempt or appreciable progress of this kind in recent years in India.

Mahatma Gandhi has roused intense enthusiasm for the uplift of the rural population. As far as I am aware, he is also in favour of industries of all classes, but the emphasis laid on *khadi* and cottage industries by him and his followers has given the public the impression that he is opposed to heavy and key industries. Both heavy and cottage industries are necessary for sound economic progress. They are complimentary to one another just as the hands and the legs are in the human body.

I am hoping that the Mahatma will one day categorically remove this impression from the public mind. I say this because his word will go far. Without modern industries to produce commodities, without modern machinery and tools to increase production, without engines for transport and munitions for defence, this country will remain crippled and stationary while other countries will be forging ahead. Unless the people of this country realise this and rectify their past, there is small chance of India ever emerging from the position of a primitive state.

AN ENGINEERING BOARD

The surest remedy to this state of things is, in my view, to bring into existence, with the approval of Provincial Governments, a Board of Engineering for four or five years, somewhat on the lines of the Tariff Board, to rectify deficiencies and organise efficienct engineering services for the country. The Board should investigate the deficiencies and handicaps of the profession and help each Provincial Government to inaugurate an efficient well-knit provincial engineering service in three to five years' time. The men appointed to the Board should be engineers of ability and experience well acquainted with foreign systems of engineering organisation, and they should be acceptable to the Central and Provincial Legislatures.

There is no reason, I can think of, to prevent or delay the inauguration of such a Board. A step of this kind would be deemed an appropriate precaution even under more settled conditions. If for any reason a Board is objected to, recourse may be had to some other parallel arrangement based on the same principles. Considering that many crores of rupees are spent annually on Civil works, the expenses of such a Board would be a mere bagatelle.

CONCLUSION

This is a time of War. One cannot withhold admiration from the British people for the sacrifices they are making, and the forethought, persistence and courage with which they are prosecuting this War. Indians too want to fight in this War by the side of the British just as other Dominions are doing at the present time. There is much disappointment felt that Indians have not been placed in a position to support the efforts of Great Britain in all her war measures in a whole-hearted

manner including the manufacture of munitions and war supplies. Psychologically, association in this war would have given a tremendous impetus to the starved energies of the nation.

Canada, for instance, is in a privileged position in this respect. If this War is protracted as the last one was, Canada will greatly benefit industrially and financially by her war effort. We rejoice at her good fortune. Before the last war, another great country, the United States, was financially a debtor country, and at the end of that war, it emerged into a creditor country, and is now the richest in the world. Good things may come for others but, for India, the heavens seem empty.

I have no wish to detain you with any further observations on this occasion. I will only add that a great responsibility rests on the members of this institution to work for the removal of the various disabilities and handicaps under which the profession is labouring. Although the work of the engineer has grown in volume and there are also more engineers than formerly, there are no broad policies to guide the services. The system of recruitment to the services is also faulty. The old system is there, but due to lack of adjustment to the present greatly altered conditions, a certain measure of disorganization or disintegration has set in. The public too need the advice and help of industrial engineers and captains of industry to be made familiar with wealth producing activities in Western lands. Our patriotic countrymen too who favour the simple life should realise the risks they are exposing our country to by continuing to preach the philosophy and methods of the bullock-cart era.

Before concluding I wish to add that the thanks of the engineers of all classes and of the general public are due to the present and past Presidents and office bearers of this Institution, both in Calcutta and in local centres, for the signal service they are rendering to the profession by their enthusiasm and sacrifices in its cause. I earnestly hope that the Institution will receive wide support, that it will grow in numbers and strength, and that its efforts to raise the dignity of the engineering profession in this country will meet with enduring success.

A General Meeting of the Institution of Engineers (India), Bombay Centre was held on Friday, 15th December 1939 at 6-15p.m. (S.T.) in the Institution Room when Mr. G. N. Gokhale, L.C.E., I.S.E.(Rtd.), gave a lecture on "Engineer as a Creator."

In the absence of the Chairman, Mr. Burjor S.J. Aga was duly proposed to the Chair.

50 members and 50 guests were present. A number of members of the Bombay Engineering Congress, who had come to Bombay for their Annual Session, attended the meeting on invitation.

The Chairman thanked the members of the Bombay Engineering Congress for having attended the meeting and suggested to them to take increasing interest in the Institution of Engineers (India).

Mr. G. N. Gokhale began his lecture by calling the Creator as the first founding member of the Society of Engineers. He could imagine a society without D.S.Ps. and Collectors, but it was impossible to dispense with the engineers. He wanted engineers to imitate the Creator in building for those for whom it was intended. He illustrated his point by citing cases of the Bombay Development Department Chawls, and of some Sind Engineers taking into their heads to have all their canals North and South and regretted that many engineers did not go into the skin of the users. The speaker thought it was a pity that 50 years were required to find that lavatories were required for 3rd class passengers. Referring to Architecture he pictured the horrible results that followed the application of heterogeneous standards. He desired engineers to follow the useful advice of Indian *Vastu Shastra* to prepare models of houses.

The speaker then stressed the importance of recognizing the limitations of the calculations based upon assumed data by giving illustrations of his experiences in the P.W.D. with regard to the design of the Lloyds Barrage and some of the Bridges in the Deccan. According to the speaker it was foolish to boast that one was absolutely correct. He advised engineers

to keep a sense of proportion and to show common sense, tact and reciprocity in all their engineering activities, which should be followed with an eye to the requirements of the users.

Mr. R. K. Nariman thanked the speaker for his instructive lecture and wished that it be printed in the Journal.

Prof. S. J. Taraporewala in a short speech showed how the engineer had much to learn from the Creator. He showed how the doctrine of reciprocity was followed in the inanimate world by giving illustrations from Castiliano's Principles and from the interesting results of the theorem of reciprocal deflections.

The President thanked the speaker for his interesting and informative lecture which was full of humourous illustrations from engineering practice.

The meeting terminated with a vote of thanks to the Chair.

A General Meeting of the Institution of Engineers (India), Bombay Centre was held on Tuesday, 26th March 1940 at 6-15 p.m. (S.T.) in the Institution Room when Mr. V. C. Mehta, B.E., Chief Engineer, Nagpur Municipality, gave a lecture on "Town Planning".

Mr. J. D. Daruvala, the Chairman, occupied the Chair.

35 members and 13 guests were present.

Mr. V. C. Mehta in opening his lecture said that the subject of Town Planning was very vast and that it involved the study of Sociology Engineering, Civil Life, Family Life etc. He proposed to deal with only some of the aspects of Town Planning, particularly the question of land policy. Mr. Mehta advocated legislation to prevent speculation in land which, according to him, killed the purpose behind the improvement of any area. He was of opinion that land should be available at a price at which it was used. Although this may sound as socialism, Mr. Mehta thought that it was but fair that profits on land should go to the community, *i.e.* the local authority, which was instrumental in initiating improvements. He then explained how the local authorities could be invested with requisite powers to acquire land by "Enabling" acts, like Federal Act, State Act, Regional Act, Local Act. etc.

He then stressed the necessity of preparing a Master Plan and explained the difference between Master Plan and Official or Layout Plan. He showed how in ancient India the science of town planning had developed to a high degree and explained the 'Swastika' and the "Nandya Varta" types of plans given in ancient Indian literature. He showed that these two types of plans were efficient in safety, in economy and in service (for instance, back lanes) etc. Mr. Mehta then showed how the rule of going by the left of the 'Tarffic Island' was adopted by ancient Indians by quoting the Sanskrit rule '*Apasa-Vyam Na Gantavyam Devagare*' *etc.*

Mr. H. D. Henman asked how the powers of acquisition which were so necessary were not given to the existing Improvement Trusts.

Mr. P. G. Dandekar explained how the profits of land did go to the State even under the present circumstances. He gave instances of non-agricultural assessment and the provision of 50% to 75% of the enhanced value of land going to the State or the Municipality in improvement schemes. He said the Bombay Municipality were trying to get powers on the lines of the English Act for removal of slums. He suggested that the congestion on roads like the Girgaum Road could be removed by broadening the footpaths by cutting only the ground floors of existing buildings, allowing the top floors to remain.

Mr. F. E. Bharucha showed how the service passages did not serve the purpose for which they were intended.

Messrs. K. D. Bhagwagar, Daruvala (a guest) and R. K. Nariman also took part in the discussion.

The President thanked the lecturer for his interesting lecture. He observed that the speculation could never be stopped by artificial methods. He was afraid that Government would only be deprived of their stamp revenue by the introduction of the "Pagri' system which was the natural outcome of any restraint on 'Speculation'. He thought that it was no use overlooking the fact that incentive given by speculation was at the root of all enterprise.

The meeting terminated with a vote of thanks to the Chair.

A General Meeting of the Institution of Engineers (India), Bombay Centre was held on Monday, 15th April 1940 at 6-15 p.m. (S.T.) in the Institution Room when Mr. E. G. Lazarus, M.I.E., gave a lecture on "Selection Tests for Engineers."

Mr. J. D. Daruvala, Chairman, occupied the Chair.

40 members and 5 guests were present.

Mr. Lazarus in opening his lecture said that an Engineer was born and not made. He created and designed things of beauty and utility and it was essential that there should be some means of testing candidates for the Engineernig Profession. He said that in advanced countries, several schools had one of the masters or mistresses trained as vocational guides and appointed to study each child in the school, watch its progress from class to class, note down its disposition, likes and dislikes, behaviour in games, manual, musical or literary abilities, so that by the time the child left school, he or she could be advised what profession would be suitable and what not. Further the Employment Bureaus in large works examined each candidate for employemnt and selected the best worker for each type of machine or type of work. Vocational advisers were to be found in large cities in the West who study the conditions and requirements of labour, and by suitable tests advise young men and women what profession or trade would suit them best. In continuing he said that misfits were the result either of ignorance in choosing a profession for which the candidate had aptitude or the choice of wrong type of men for particular jobs. He gave instances of misfits that he had come across.

He said that the requirements for selecting the right people for the right job were briefly : (1) Medical Examination which should cover physical fitness such as dexterity of hands and fingers, eye-sight, acuity of hearing, condition of the heart, blood pressure, neurological examination, gait, malfunctioning of Endocrine Glands etc. (2) General Knowledge—prior to testing candidates for general knowledge it was necessary for the vocational adviser to collect data from the candidate regarding his social, financial and other circumstances, and the occupations of other members of the family. The Vocational adviser should meet the parents and gather from them in formation regarding temperamental and other traits of the lad. School

reports furnished other evidence that would be useful to the adviser. (As it was not possible to give in detail particulars of the written examination to which the candidate was subjected, slides were shown giving some idea of what they were like.) In continuing Mr. Lazarus said that in general the tests were wide, and required no text book or special instructions. They aimed at elucidating the candidate's ability to think, read, understand, reason and act quickly and some of the written tests also gave indications of ability for leading professions. (3) Practical tests which were designed to bring out the ability to check mechanical devices, the use of hands, eyes and muscles that would be needed for a particular job. (4) Guidance regarding choice of profession. After obtaining all the above information the Adviser, who had made a study of and kept in touch with the requirements of professions and trades, advised the candidate in what profession he was likely to be successful. Two or three alternative trades or professions were suggested in each of which there were indication from the tests that the candidate would find interesting and profitable.

In conclusion the lecturer stressed the need for vocational guidance in this country and expressed the hope that Engineers would give it an encouragement. It was also pointed out that the proper selection of employees tend to reduce accidents in factories and workshops. The men liable to accidents were those who had a tendency to worry over trifles. Such men were apt to do things forgetfully. The careless and untidy person was slovenly in his movements and may accidentally operate levers and mechanisms. Fatalism, which was so common in this country, was another contributory cause of accidents, as the man believed that he would meet with no accident whatever he did, unless he was fated to die. To overcome these tendencies in one's personnel it was essential that steps should be taken to form instinctive principles for safety. This may be done by constantly drawing the attention of the staff to safety first principles by posters, lectures, drills and the like. These principles would gradually be absorbed by the subconscious mind and at the time of hazard make the man respond to the urge of safety from within him.

Mr. Nadirshah drew the attention of the lecturer to the fact that he had not touched the question of "Common Sense" and "Power of eye to detect errors".

The President congratulated the lecturer for his interesting and instructive lecture and proposed a vote of thanks to him, which was carried unanimously.

The meeting terminated with a vote of thanks to the Chair.

A General Meeting of the Institution of Engineers (India), Bombay Centre, was held on Tuesday, 14th May 1940 at 6-15 p.m. (S.T.) in the Institution Room when Mr. H. D. Henman, A.M.I.E., gave a lecture on "Relations of the Store-Keeper with the Workshops."

In the absence of the Chairman, Mr. Framroz D. Mehta was duly voted to the Chair.

40 members were present.

Mr. H. D. Henman in opening his lecture said that the functions of a store-keeper was in some cases associated with purchase but in large associations store-keeping and purchasing were separate, especially so in America. One of the most important things any one had to consider in dealing with stores was the type of man required to run the organisation. As far as he was aware, there were no institutions giving training for store-keeping, though in America there were institutions which presumed to do so on broad principles. It was surprising that people became store-keepers as if by accident and in most cases it was found that the store-keeper had started in some other line of work. To be a store-keeper a man must have a methodical and orderly mind with business instincts. He should not be engrossed with theories but what was required was a practical man whose training was such as to give broad outlines on the functions of engineering. Further he should have some workshop training and greater the opportunities he had had on the uses of materials in the workshop, the more he was likely to succeed. A store-keeper should not be bluffed by people who had prejudices for certain brands of materials but should know the purpose and objects of every material with which he came in contact.

Mr. Henman further said that there was a great amount of clerical work for a store-keeper and he should have training in fundamentals of mechanics, physics, etc., as such knowledge

would certainly avail him in his job. In former times the foreman was usually his own store-keeper, but as time progressed the work of store-keeping was taken over from the foreman or the manager and entrusted to a specialist. The duty of a store-keeper was to see that the material required was available, that the work was not delayed, and to deliver the stores required at the required place, as soon as possible. It was surprising to see variety of functions and variety of materials, at times required of the store-keepers.

Mr. Henman concluded that the service could only be rendered properly if all co-operated with him, encouraged him and what was more important, supplied him with fullest information so as to enable him to obtain proper materials. It was also the duty of the indentors to inform the store-keeper of any change in the type of material to be used, so that he would be prepared beforehand.

Mr. J. G. Kulkarni related his experience with the store-keepers, and complained that they sometimes supplied materials which were either bad or rusty and not in proper condition. He gave instances of indentors not supplying proper and fullest information to the store-keeper which resulted in materials being bought from abroad even though they were obtainable locally.

Mr. E. G. Lazarus explained the method employed in store-keeping in the Bombay Electric Supply and Tramways Co., Ltd.

Mr. Henman replied that it was wrong, as decided by the Audit, that the store-keeper should not know the value of materials in his charge, as it was thought that the staff would be tempted to steal. He then explained some of the difficulties in obtaining materials in India, as agencies of the firms dealing in them changed very often. He also explained the necessity of standardizing the nomenclature of different materials and suggested that the indentors should, as far as possible, use the same term when ordering same materials, from time to time.

The President thanked Mr. Henman for his interesting lecture.

The meeting terminated with a vote of thanks to the Chair.

CONSERVATION OF COAL.

Abstract of Lecture delivered by Nawab Ashan Yar Jung Bahadur, Member, at the Hyderabad Centre on 27th June, 1940.

Coal is an exhaustible commodity. It must be conserved by the process of low temperature carbonisation using only soft coke for production of power and domestic heating instead of raw coal; and thus burning also the valuable volatile Hydro-Carbon contents which can with advantage be utilised to enrich the national resources of the Country.

2. The advantages in adopting such a course are:

I. Improving the health of the population of towns by not polluting the atmosphere.

II. Prevention of waste of valuable Hydro-Carbons contained in Coal.

III. Production of valuable products from Coal Tar.

IV. Manufacture of Ammonium Sulphate.

V. Utilisation of resulting soft coke for raising steam in production of Electric Energy and for domestic heating.

VI. Production of large quantities of Gasoline or Motor Spirit by Hydrogenation.

3. The most economical means of applying power to Industries is by using electric energy generated by Hydro or Thermal Plants. Both the resources are available in the Hyderabad Dominions. In 1937, the quantity of coal quarried and sold by the mines in the Hyderabad State was nearly one million tons. If this quantity had been carbonised and hydrogenated, the products would have been:

Soft Coke	..	7,00,000 tons.
Tar	..	15,000 ,,
Ammonium Sulphate	..	5,000 ,,
Gasoline	..	1,50,00,000 gallons.

These products which are now lost, would have, if utilised, enriched the national wealth. It has been agreed by experts that the magnetic ore available in the Hyderabad Dominions is more amenable to treatment in electric furnaces. Soft coke can be used for production of electric energy, to be utilised for manufacture of steel in electric furnaces when sufficient Hydro-Electric Power is not available from the River Godavari during the six dry months of the year.

4. For utilising the rich magnetic ore with Fe 46 to 66% roughly estimated to be nearly 100 million tons by Mr. Laik Ali in Amberipet area, within 20 miles of Kazipet Balharshah Railway, the proposal is to instal a steel making plant at Antargaon on the right bank of the River Godavari, for an annual production of 50,000 tons as a first stage and duplicate the works when demand is increased. The Ambaripet area alone can supply ore to the steel works for more than 500 years, even if, 1,00,000 tons of steel are produced annually as the quantity of ore required will be 3,00,000 tons with a fair margin for wastage.

5. For the first stage of production of 50,000 tons of steel the hydro-power available for six months, will be 24,000 kW. delivered at site of works, and during the remaining six dry months, only 3,000 to 6,000 k.W.; the balance of 18,000 to 21,000 kW. being supplemented by thermal plant installed at the Steel Works. The thermal plant will require for six months at least, 1,40,000 tons of soft coke, which can be produced from 2,00,000 tons of raw coal, according to the experiment carried out at the Industrial Laboratory. By establishing a carbonisation and hydrogenation factory at Bellampalli adjoining the coal mines, the coal can be purchased at Rs. 2/8/- per ton and the soft coke sold to the Steel Works at Rs. 3/- per ton. The by-products of the above quantity of coal will be approximately :—

Soft Coke	..	1,40,000 tons.
Tar	..	3,000 ,,
Ammonium Sulphate	..	1,000 ,,
Gasoline	..	30,00,000 gallons.

6. The approximate cost of Hydrogenation Plant will be one Crore of Rupees and the manufacturing cost of Gasoline allowing 4% interest on capital, depreciation, etc., will be about five annas per gallon as shown below :—

Cost of Manufacture of Gasoline (3,000,000 gallons).

2,00,000 tons of Coal @ Rs. 2/8/- per ton		B.G. Rs.	5,00,000
Chemicals, etc.		,, ,,	1,30,000
Establishment charges including wages, etc.	Rs. 1,00,000		
Depreciation 2½% on One Crore ..	2,50,000		
Interest @ 4% on One Crore ..	4,00,000		
Overhead charges, etc. ..	2,00,000		
		,, ,,	9,50,000
	Total Cost	B.G. Rs.	15,80,000
Credits by Sale of :—			
1,40,000 tons of coke @ Rs. 3/- per ton	Rs. 4,20,000		
3,000 tons of Tar @ Rs. 40/- per ton ..	,, 1,20,000		
1,000 tons of Ammonium Sulphate @ Rs. 100/- per ton ..	,, 1,00,000		
		,,	6,40,000
Net cost of 3,000,000 gallons of Gasoline		B.G. Rs.	9,40,000

Or five annas per gallon.

With excise duty at six annas per gallon and allowing only four annas profit, Gasoline can be sold at fifteen annas per gallon and the net profit after paying interest charges will be 7·5 lakhs or 7½% on capital.

The profit to Government will be 11·25 lakhs as excise revenue at six annas per gallon and if half the capital is provided by Government, the profit will be 3·75 lakhs more or in all 15 lakhs, *i.e.*, 30% on the capital invested.

7. The progress on the development of low temperature carbonisation industry has been slow in England though an enormous amount of research has been carried out during the

last 10 years. Had she adopted the system earlier, there would have been no shortage of petrol to-day. Nearly half the total consumption of petrol in the continent of Europe is met by Gasoline produced from coal.

Out of the total annual output of over 300 million tons of coal in the United Kingdom, 200 million tons are stated to be reserved for home consumption. If this 200 million tons were carbonised, the annual production of Gasoline would have been over 3,000 million gallons besides the other valuable by-products.

A Fuel Research Board was appointed in Great Britain and a research station has since been established at Greenwich, London. Low temperature carbonisation has been intensively studied and some 1,600 tons of coal were treated by this method in 1927.

8. Experiments are being carried out at the Industrial Laboratory, Hyderabad, but not having proper equipment, the research cannot be conducted in a Plant of a size used in commercial practice. A fuel research section should be established at the above Laboratory purchasing a small Pilot Plant from England or America with a capacity for treating not more than one ton of coal per day.

Major Croslegh, Agent of Singareni Collieries in London, has also recommended that after Laboratory tests are satisfactory, a Pilot Plant should be installed to ascertain if the process will be a commercial success.

The cost of the smallest Pilot Plant was about £2,500 before the War and an American Plant may now cost £3,500 or O.S. Rs. 55,000

Add (1)	Carriage, Buildings, erection, etc. ..		20,000
(2)	Catalysts, Chemicals, etc., for tests of 300 tons of coal ..		10,000
(3)	Extra Establishment, etc., for one year ..		15,000
	Total ..	O.S. Rs.	1,00,000
		or B.G. Rs.	86,000/-

The total cost of the Pilot Plant and detail tests for one year will be only O.S. Rs. One Lakh which is not very much considering the expenditure of £80,000 to £90,000 per annum incurred in England. This fuel research section can also test the suitability of other fuels in the Dominions for production of cheap power.

Finally, it is hoped that Government will sanction the above sum of Rs. One Lakh for the present for one year for Coal Research to the Industrial Laboratory which should be under the control of an Industrial Research Board.

CONTROL OF SUB-SOIL WATER LEVEL.

Abstract of Paper read by Mr. Ram Kishore, Associate Member, at the Annual General Meeting of the U.P. Centre held at Agra on the 26th November 1939.

In most places in Northern India, there is a very large quantity of water in the sub-soil, this is used for water-supply for domestic and industrial purposes and for Irrigation, and is replenished by that portion of the rainfall which sinks into the ground. There is also a very slow flow of the sub-soil water from higher to lower levels.

This sub-soil water forms a sub-soil reservoir as well as a sub-soil river. The author tries to show that the reservoir aspect is much more important than the river aspect. If large quantities of water equal to or greater than 5 per cent of the rainfall are regularly added to or withdrawn from the sub-soil, there will be a very appreciable permanent rise or fall in the sub-soil water level.

The Author discusses various artificial methods by which sub-soil water level is or can be permanently changed, either intentionally or unintentionally causing desirable or undesirable effects.

THE JOURNAL
OF
The Institution of Engineers (India).

Vol. XXI **August 1941.** **No. 2**

Journal Committee

The President.
P. E. Golvala,
A. R. Nisser,
Tech. Secy.

The Institution of Engineers (India) as a body accept no responsibility for the statements made in the Journal.

Correspondence on all controversial matters is invited and will be published in the Journal if approved by the Journal Committee.

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This issue 1650 Copies.

Address all Communications to—

A. R. NISSER, E.E. Hons. (U.S.A), D.I.C. (London).

Technical Secretary

THE INSTITUTION OF ENGINEERS (INDIA).

Telegrams "ENJOIND" **8, Gokhale Road, Calcutta.**

A MESSAGE FROM THE PRESIDENT

To All Corporate Members

Gentlemen,

With the publication of the second issue of our Quarterly Journal I take the opportunity of addressing a few words personally to all my professional brethren throughout India on a matter of vital importance to our Institution. There is no doubt that our Institution has by now grown sufficiently in strength and eminence so as to hardly need any message of appreciation or commendation from me, but I venture to think that there is still a large scope for expansion of its activities in many directions. The main object of this Institution, as you know, is the diffusion of higher technical knowledge relating to various engineering problems among its members by means of journals and other publications as well as by periodical meetings and to increase the general level of their education and experience. There is a vast amount of literature published now-a-days on engineering matters It emanates from many sources and from many countries in an infinite variety of forms so that it is impracticable for every individual member of the profession to see it all. The Institution feels that it is its foremost duty to bring to the knowledge of its members modern tendencies in engineering not only in this country but all over the world as far as it lies within its scope and power and to keep them informed of all the important work which is being done and of the developments which are taking place in the world. Ideals such as these, however, cannot obviously be realized without money. The chief source of revenue of the Institution is the subscription for membership. In a vast country like India, there must be not less than 10,000 Engineers possessing the requisite qualifications for membership of our Institution. You can imagine what amount of work can be done for the profession of Engineers if we have at our back a membership 10,000 strong. Apart from the funds that increased membership will bring, we will have the advantage of increasing the general level of our knowledge and experience by inter-communication through our Journal and periodical meetings and we will then be a great force in moulding the destinies of India. This is no mere dream. I am confident

that by the co-operation of you all we can achieve this ideal at no distant date and I appeal to you to consider it your duty to bring to the notice of all Engineers possessing the requisite qualifications the great advantages that will accrue to them in particular and to India in general by their joining this Institution.

It is not merely by increasing our membership that we can grow. You will all make it a point to share your experiences in your career as an Engineer with other Engineers through Institution Papers, Talks at the Local Centres or through the correspondence column of our Journal and thus assist in the further development of the Institution which is doing such splendid service in the cause of Engineering.

The Commonwealth of Nations is engaged in a great war in which an engineer can render valuable service to his country next only to the brave soldiers fighting in the front. I am sure every one of us is doing his duty at this critical hour. To supply the manifold requirements of the war, India is entering an era of Industrialization. In order to solve numerous problems that confront the Industries, it requires thinking and planning by the Engineering profession. This can only be done through the medium of our Institution. It may not be out of place to mention that this Institution owes its birth to the industrial upheaval created during the last Great War.

I therefore again appeal to you to make this Institution a great force by bringing all Engineers of the requisite qualifications within its fold and by taking an increasing interest yourself in the varied activities of this Institution.

It may not be possible for me to meet personally every one of you, but I will try to meet as many of our members as possible at the different meetings of the Local Centres whenever I get an opportunity to visit such Centres.

N. V. MODAK,

President.

21-7-41.

DESIGN AND CONSTRUCTION OF THE ANDERSON BRIDGE

BY

JOHN CHAMBERS,[1] *Member, O.B.E., M.C., A.M. Inst. C.E., M.I. Struct. E., I.S.E.*

The "Anderson" Bridge across the Teesta River

The bridge, which is the largest single span reinforced concrete bridge constructed in India to date crosses the Teesta River with an arch of 292½ ft. clear span, effective span 300 ft. and a rise of 50 ft. On the Teesta side are three 30 ft. straight shore spans and on the Kalimpong side one 30 ft. straight and two 30 ft. curved spans (see Plate II). The breadth of the roadway is 19½ ft. between railings and 18 ft. between curbs, 9 inches on each side being necessary to prevent damage to railings by the projecting hubs of bullock carts The arch was designed as a fixed arch, temporary hinges being used during construction. The two I section ribs increase in depth from 6 ft. at the crown to 6 ft. 7½ inches at the springing and are connected at 15 ft. centres along the span by stiffeners.

The bridge was designed to carry one ten ton roller fully loaded plus a crowd load of 84 lbs. per square foot on roadway not occupied by roller. A variation in temperature of 40 degrees Fahrenheit was taken into account when checking stresses. The arch axis was made to conform to the line of pressure for the dead load. The reinforcement consists of 1¼", 1", and ¾" dia mild steel bars arranged as follows:

Crown	..	Each flange	outer edge	12 φ 1¼'
			inner edge	4 φ ¾"
Springing	...	,,	outer edge	12 φ 1"
				12 φ 1"
			inner edge	4 φ ¾"

In addition to the longitudinal reinforcement ⅜" rectangular spirals of 3" pitch are provided in both flanges and web. Stiffeners connecting the two ribs are provided where the loads from the superstructure are applied to the arch thro' the columns. The superstructure was, considering the size of the arch, made as light as possible, and consists of reinforced concrete columns which carry the longitudinal beams and cross-beams with deck slab on top. The columns are 17" × 17" and are reinforced with 8-1" dia. bars connected at 9" centres with ⅜" dia. stirrups. For a length of 45 feet on each side of the crown the longitudinal beams are substituted by ribs placed directly over the arch. The longitudinal beams or ribs and the cross-beams are spaced at 15 feet centres, thus making the road slab a system of 15 ft. × 15 ft. panels with 2'-3" cantilevers to carry kerb and railings (for details see plates VIII and X).

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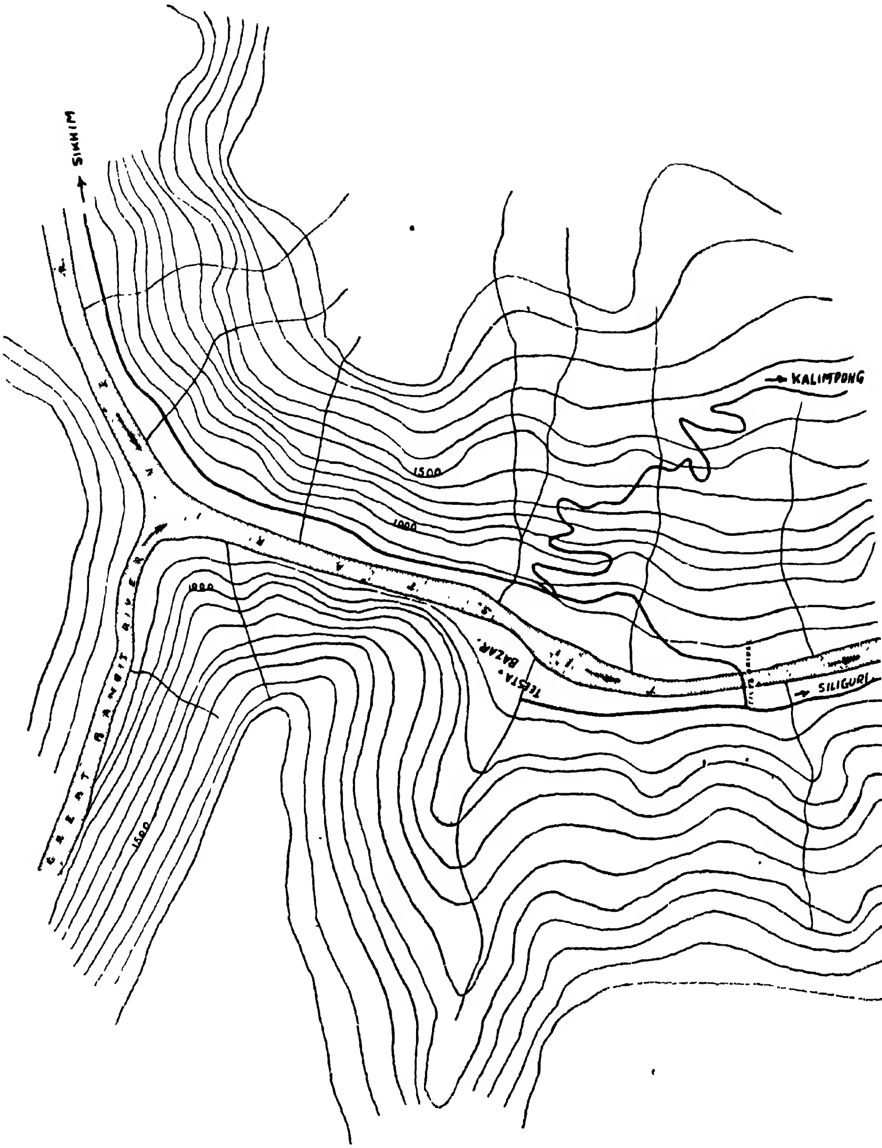
1. Superintending Engineer, Northern Circle, Bengal

Notes —(i) Written comments are invited for publication.

(ii) This paper will be discussed at the next Annual General Meeting.

(iii) The Author submitted 11 large drawing plates all of which however could not be reproduced, but these are open to members for inspection at Headquarters during office hours

T. S.



Site Plan-Teesta Bridge

Plate I.

Construction of Main Arch Abutment and Approach Bridge, Teesta Side.—(Plan on page 264) shows the site of the bridge and Fig. 1 a view of the hillside when work commenced. A dry rubble wall had been built to prevent erosion of the bank and also as a protection to the existing suspension bridge. Before work commenced trial pits were dug behind this wall and as only loose filling was found a certain amount of trouble was expected when excavation began, this, however, did not materialize as long as the weather remained fine. The foundation of the main arch was on fairly hard micaceous schist ; this rock, however, very quickly disintegrated when exposed to moisture.

Fig. 1.—View of Hillside before work commenced.

Fig. 2.—Slip covering foundations.

Work was commenced on March 9, 1931 and by the middle of June the work had reached the stage that a small amount of structural concrete was placed to hold the main arch reinforcement in position. Heavy monsoon rain began about the middle of July and on the 27th July a heavy slip occured, see Fig. 2.

From this time upto the end of the Pujas numerous slips occurred due to the sides of the excavation disintegrating and falling onto the main abutment. Clearing of slips began on 23-9-31 and was completed on 13-10-31 ; a further slip occurred on 6-11-31 due to cutting back for foundation of first pier of approach bridge, this was cleared and placing of steel was commenced on 23-11-31. Concreting recommenced on 24-11-31, after a break from 6-7-31 and main arch foundation was completed sufficiently to allow the erection of the shore wall to approach span by 2-2-32. See Fig. 3.

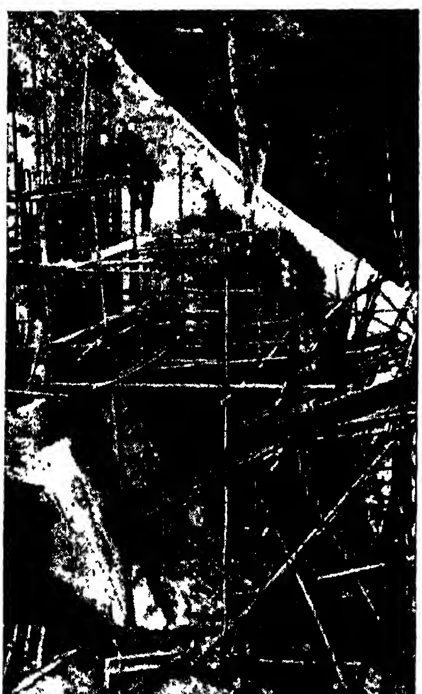


Fig .3.—Commencement of shore wall to approach bridge.

Fig. 4.—Showing condition of ground under approach bridge before dressing.

Approach Bridge—Foundations.—Excavation, which consisted of removing disintegrated schist, was commenced on 2-9-31, but due to heavy rain and slips concreting of the foundation could not be commenced until 15-11-31. The piers and abutment were completed on 18-2-32.

Superstructure.—This consists of three thirty feet spans, the roadway being carried on four main beams 33 inches × 14

inches connected by 27 inches × 8 inches stiffeners at 10 feet centres. The free ends of the beams rest on cast iron rockers placed on top of the shore wall and abutment respectively. The columns supporting the beams are connected by bracings. Expansion joints are provided above the abutment and between the shore walls to allow for movements due to temperature, etc. Construction of the shore wall was commenced on 10-2-32 but was not completed until 5-4-32 due to lack of suitable form work. Concreting of the superstructure commenced on 27-4-32 and was completed on 7-5-32.

Owing to the danger of slips the hillside was carefully dressed and turfed. To prevent water getting in behind the abutment, the ground under the bridge, after filling, was dressed, soled and covered with 3 ins. weak concrete, drains being formed at the sides to carry water direct into river. Fig. 4 shows condition of ground under approach bridge before dressing, etc., commenced.

Note method of supporting shuttering—steel joists, one end resting on openings in shore wall and the other on cross bracing, the bracing being propped from the ground.

Construction of Main Arch Abutment and Approach Bridge, Kalimpong Side.—Excavation, which consisted chiefly of disintegrated micaceous schist was commenced on 23-3-31, this gave no trouble and was completed on 7-6-31. Concreting commenced on 6-6-31 and foundation was raised above ordinary flood level by 23-6-31. From this date upto 8-1-32 continual trouble was encountered, chiefly from slips as will be seen from the following table.

Date of slip.	Date on which foundation was cleared and ready for concrete.
26-6-31	30-6-31
1-7-31	3-7-31
15-7-31	16-7-31
19-7-31	17-8-31
23-9-31	12-12-31
13-12-31	8-1-32

Excavation for first pier of approach bridge was completed and ready for concrete on 12-12-31 but on 13-12-31 a slip occurred involving collapse of the temporary bridge on the Rishi road directly above the abutment.

The ground behind the main abutment proved, on opening up to be very variable, consisting of decomposed schist, badly fissured, hence it was decided to cover the ground between abutment and end of excavation with a concrete raft. (See Plate II.) This was completed on 8-1-32 and concreting began on the same day. Foundations and columns to beam level were completed on 19-3-32. Excavation for second pier commenced on 2-2-32 and was completed on 10-2-32. Foundations and columns to beam level completed on 22-3-32. Excavation for abutment commenced on 22-3-32 and completed on 23-4-32. Concrete to rocker level completed on 2-5-32. Fig. 5 shows abutment, shore wall and first pier in progress.

Fig 5.—Showing main foundation completed.

Approach Bridge.—This consists of three spans of thirty feet, one straight and two curved. (See Plate II.) The same type of construction was used as explained under approach bridge Teesta side. Concreting of the superstructure was commenced on 20-5-32 and completed on 25-5-32. Ground under bridge was dressed and treated in a manner similar to the Teesta side. Table I gives details of cost of shore spans.

Plate II

With Compliments of

THE TECHNICAL SECRETARY

THE INSTITUTION OF ENGINEERS (INDIA).

8, GOKHALE ROAD, CALCUTTA.

TABLE I

Basic Costs Approach Bridges, Teesta Bridge
(excluding cost of supervision, tools and plant profit, etc.)

Item of work.	Teesta Side. Quantity.	Teesta Side. Cost.	Teesta Side. Rate per Cu. ft. of concrete in annas.	Teesta Side. Cost of R.C. per Cu. ft	Kalimpong Side (curved). Quantity.	Kalimpong Side (curved). Cost	Kalimpong Side (curved). Rate per Cu. ft. of concrete in annas.	Kalimpong Side (curved). Cost of R.C. per Cu. ft.	Cost of shuttering per sq. ft. in annas. Teesta Side.	Cost of shuttering per sq. ft. in annas. Kalimpong Side.
				Rs.				Rs.	as.	as.
Excavation ...	...	432 6 0	..		..	1,355 4 0	...			
Shuttering for 1st pier ...		157 0 0	0 86		...	163 14 0	0 75			
,, for 2nd pier ...		213 4 0	3·26		...	154 13 0	1·05			
,, for abutment ...		165 9 0	1·12			134 10 0	0·62			
Concrete in position 1st pier	2,932 Cu. ft.	1,999 8 0	10·90		3,484 Cu. ft.	2,030 4 0	9 32			
,, ,, 2nd pier	1,045 Cu. ft.	758 1 0	11·60		2,356 Cu. ft	1,383 12 0	10·50			
,, ,, abutment	2,362 Cu. ft.	1,351 3 0	9·15		3,490 Cu. ft	2,102 13 0	9 65			
Shuttering Shore span columns	840 Sq. ft.	193 3 0	8·85		840 Sq. ft.	198 0 0	9·06		3·68	3·76
Reinforcement shore including bending, etc. ...	26 Cwt.	445 12 0	20 40	3·28/-	26 Cwt.	316 2 0	14·45	2·74/-		
Concrete shore in position ...	350 Cu. ft.	510 12 0	23·30		350 Cu. ft	441 13 0	20·20			
Shuttering shore wall ...	1,730 Sq. ft.	371 14 0	5·24		1,730 Sq. ft.	460 2 0	6·48		3 42	4 26
Reinforcement shore including bending, etc. ...	279 Cwt.	499 7 0	7·06	1·72/-	279 Cwt.	370 9 0	5 21	1·5/-		
Concrete shore in position ...	1,136 Cu. ft.	1,075 11 0	15·18		1,139 Cu ft	877 8 0	12·33			
Shuttering and centering per shore span beams and stab.	4,619 Sq. ft.	3,046 10 0	21 0		4,619 Sq ft.	2,473 15 0	8·56		10·6	8·56
Reinforcement ditto including bending, etc. ...	212 Cwt.	3,143 15 0	22·3	3·78/-	212 Cwt.	2,496 1 0	17 15	3·27/-		
Concrete ditto in position	2,327 Cu. ft.	2,494 15 0	17·15		2,327 Cu. ft.	2 642 8 0	18·15			
Earthwork in dressing and filling ...	...	50 7 0	...	...	..	211 5 0	...	...	...	...
		16,888 5 0				18,366 9 0				

Steel Centering.—The Teesta river is fed by numerous mountain streams and also by melting snow from the Himalayas consequently the river is apt to rise very rapidly and to bring down a large amount of drift timber, etc ; for this reason supports of any kind were considered impossible in the bed of the stream and consequently the centering was designed so as to be clear of the water when the river was in flood. A two hinged arch was considered the most suitable, this consisted of two steel arched trusses, one under each concrete arch rib. The loads coming on the centering were calculated, (see tables II and III) and the axis of the steel rib made to coincide with the line of pressure in order to avoid bending in the rib. As the centering has only to carry its load for a comparatively short length of time a reduced factor of safety was considered sufficient, (see table VIII which gives the factor of safety available). The steel arch ribs were carried on cast iron hinges, these weighing about five tons each. As the only method of transporting material across the river was the existing suspension bridge, which was only allowed to carry one loaded bullock cart manhandled at one time, the question of carrying the hinge across the bridge became an important point. The bridge was temporarily strengthened

Table II.

LOADING FOR ONE ARCH RIB.

Weight of Centering	= 32·5 tons.
Extra weight of each hinge	= 1 ton.
∴ weight of centering at each panel ...	$= \frac{32{\cdot}5}{42} = 0{\cdot}77$ tons
Weight of concrete at each panel	= 5·12 tons.
Extra near Crown	= 1·87 tons.
Extra at Crown	= 1·08 tons.
Extra near Springing	= 1·23 tons.
Weight of shuttering at each panel	= 0·76 tons.
Total weight of Shuttering and Centering and concrete per panel	= 0·76
...	0·77
...	5·12
...	= 6·65 tons.
∴ weight for each truss on each panel	$= \frac{6{\cdot}65}{2} = 3{\cdot}325$ tons

The loadings at each panel point are given in table III.

Table III

V. Loading of the truss

Loadings in tons due to

	Centering	Extra Due to Hinge.	Shuttering	Shock.	Concrete	Extra Due to Solid Section.	Bracings	Total
1	...	$\frac{1\cdot0}{2}$	...	...	. .	...	...	0·50
2	$\frac{0\cdot39}{2}$	$\frac{1\cdot0}{2}$	. .	...	.	...	...	0·70
3	0 39	...	0 19	0 09	2 56	0·62	0·74	4 59
4	0·39	. .	0·38	0 09	2 56	...	0·62	4·04
5	0·39	...	0 38	0·09	2·56	. .	0 27	3·69
6	0·39	..	0·38	0·09	2·56	...	1 09	4 51
7	0·39	...	0 38	0·09	2·56	...	. .	3·42
8	0·39	...	0·38	0 09	2·56	...	1·08	4·50
9	0 39	...	0·38	0·09	2·56	...	0 28	3·70
10	0·39	...	0·38	0·09	2 56	...	0·72	4·14
11	0·39	...	0·38	0·09	2·56	...	0·64	4·06
12	0·39	...	0·38	0 09	2 56	.	0 56	3 93
13	0·39	...	0·38	0·09	2·56	...	0 85	4·27
14	0·39	...	0·38	0·09	2·56	...	0·32	3·74
15	0·39	...	0·38	0·09	2 56	...	1·04	4 46
16	0·39	...	0·38	0 09	2·56	...	0·19	3 61
17	0·39	...	0·38	0·09	2·56	...	1 17	4·59
18	0·39	...	0·38	0 09	2·56	...	0·09	3·51
19	0·39	...	0·38	0·09	2·56	...	1 27	4·69
20	0·39	...	0·38	0·09	2 56	...	0·06	3 48
21	0·39	...	0·38	0·09	2·56	...	1·30	4·72
22	0·39	...	0·38	0·09	2·56	0·94	..	4·36
23	0·19	...	0·19	0·09	1·28	0 54	1·36	3·65
							Grand Total	86·86 tons

Table IV

Calculations for Horizontal thrust.

Panel points.	Distances from the Crown, a (ft.)	Forces, F (tons.)	F x a (ft.-tons)	Bending moment due to the Vertical forces (ft.-tons.)
23	0	3·65	0	0
22	7·38	4·36	32·1	32·1
21	14·75	4 72	69·5	101·6
20	22 08	3·48	76·8	178·4
19	29·33	4 69	137·7	316·1
18	36 63	3·51	128·6	444·7
17	43·92	4 59	201 8	646·5
16	51·17	3·61	184·7	831·2
15	58·38	4·46	260·0	1091·2
14	65·5	3·74	244·8	1336·0
13	72·5	4 27	309·7	1645·7
12	79·63	3·93	312·4	1958·1
11	86·58	4·06	351·0	2309·1
10	93 42	4.14	387·2	2696·3
9	100·17	3·70	371·0	3067·3
8	016·75	4·5	480·0	3547·3
7	113·42	3·42	388·0	3935·3
6	119·83	4·51	538·2	4473·5
5	126·17	3 69	466·0	4939·5
4	132·17	4·04	534·5	5474·0
3	138·17	4·59	636·0	6110·0
2	141·75	0·70	99·2	6209·2
1	143·5	0·50	71·8	6281·0

$$\text{Horizontal thrust} = \frac{143{\cdot}5 \times 86{\cdot}86 - 6281}{48} = 128{\cdot}5 \text{ tons}$$

Table V

Calculation for the total moment about the panel points on the top boom.

Points.	Vertical distances a (ft.) from springing.	Horizontal force H (tons.)	H x a (ft.-tons)	Horizontal distances b (ft.) from springing	Vertical forces V (tons.)	Vl (ft.-tons)	EVl (ft.-tons)	Total moment H.a– EVl (ft.-tons)
1	0	128·5	0	0	86·86	0	0	0
2	3·15	,,	404 5	1·75	86·36	151 2	151 2	253 3
3	9·25	,,	1188·0	3 58	85·66	307 0	458·2	729·8
4	12·90	,,	1658	6·00	81·07	486 4	944·6	713 4
5	16·65	,,	2135	6·10	77·03	470 0	1414 6	720·4
6	20·15	,,	2592	6·34	73·04	459·0	1873·6	718 4
7	23·75	,,	3050	6·51	68·83	448 0	2321 6	728·4
8	27·10	,,	3480	6·67	65·41	437 0	2758·6	721·4
9	30·30	,,	3890	6·58	60·91	402·0	3160·6	729·4
10	33·15	,,	4264	6·75	57·21	386·0	3546·6	717 4
11	35·95	,,	4616	6·84	53·07	363·0	3909·6	706·4
12	38·50	,,	4943	6·95	49·01	341·0	4250·6	692 4
13	40·85	,,	5260	7·00	45·08	315 3	4577·9	682 1
14	43·20	,,	5540	7·06	40·81	288·5	4866 4	673 6
15	45·15	,,	5802	7·12	37·07	263·0	5129·4	672·6
16	46·85	,,	6019	7·17	32·61	233·5	5362·9	656·1
17	48·35	,,	6214	7·20	29 00	208 18	5371·7	642·3
18	49·65	,,	6377	7·23	24 41	176·4	5748·1	620·9
19	50·75	,,	6511	7·27	20·90	151·2	5899·3	611·7
20	51·45	,,	6615	7·30	16·21	118·4	6017·7	597·3
21	52·20	,,	6700	7·33	12 73	92 9	6110·6	589·4
22	52·35	,,	6730	7·37	8·01	59·0	6169·6	560·4
23	52·60	,,	6758	7·38	3·65	27·0	6196·6	561·4

Table VI

Calculation for the total moment about the panel points on the bottom boom.

Points.	Calculation of the moments of the Vertical forces.		Vertical distance from springing a (ft.)	Horizontal force (ton) x a or 128·5 x a.	Total moment (ft.-tons)
1		...	...	...	0
2	1 75×86·36=151·2+1·7×85·66= 151·2+147·1	298·3	·24	30·8	267·5
3	298·3+6·9×85·66−5×4·59= 298·3+591−22·9	866·4	1 30	167·0	699·4
4	866·4+5·8×81·07−4·75×4·04	1317·2	4·95	635 0	682·2
5	1317·2+5 85×77·03−4·75× 3·69	1750 7	8·45	1086·0	664·7
6	1750·7+6·4×73·34−4·5×4·51	2199·4	12·05	1548·0	651 4
7	2199·4+6·4×68 83−4·25×3·42	2625·9	15·50	1990·0	635·9
8	2625·9+6·4×65·41−4×4·5	3022·9	18·60	2395	627·9
9	3022·9+6·4×60·91−3·75×3·7	3398·0	21·75	2794	604·0
10	3398·0+6·5×57·21−3·5×4·14	3755·5	24·75	3172	589·5
11	3755 5+6·5×53·07−3·25×4·06	4087·3	27·30	3505	582·3
12	4087·3+6·75×49·01−3·00×3·93	4406·5	29·8	3829	577·5
13	4406·5+6·75×45·08−2·75× 4·27	4698·7	32·15	4130	568·7
14	4698·7+6·8×40·81−2·5×3·74	4966·8	34·3	4406	562·8
15	4966·8+6·8×37·07−2·25×4·46	5209·0	36·25	4660	549·0
16	5209+6·85×32·61−2·0×3·61	5425·3	37·85	4874	551·3
17	5425·3+6·85×29·00−1·75× 4·59	5615·8	39·40	5060	555·8
18	5615·8+7×24·41−1·5×3·51	5781·4	40·5	5204	577·4
19	5718·4+7×20·90−1·1×4·69	5922·6	41·5	5325	597·6
20	5922·6+7×16·21—·8×3·48	6033·3	42·25	5423	610·3
21	6033·3+7×12·73—·5×4·72	6120·0	42·80	5500	620·0
22	6120+7·1×8·01—·25×4·36	6175·7	43·20	5551	624·7
23	6175·7+7·1×3·65—0×3·65	6201·6	43·40	5576	625·6

Table VII

Stresses in the members of top chord.

Member.	Area (sq. in.)	Moment (ft.-tons)	Distance (ft.)	Total stress in tons.	l (in.)	r (in.)	l/r	Crippling Load according to Dorman Long's Hand Book: per sq inch.	Crippling Load according to Dorman Long's Hand Book: Total	Factor of Safety
1-2	...	267·5	2·7	99·0	Solid portion			of Hinge		
2-3	8·72	699·4	8·25	84·2	84″	1·85	45·4	...	196	2·33
3-4	8·72	682·2	9·25	74·4	87″	1 85	47	...	194	2 63
4-5	8·72	651·4	9 25	70 6	87″	1·85	47	...	194	2·77
5-6	8·72	635·9	9 25	71·0	87″	1·85	47	...	194	2 74
6-7	8·72	621·9	9·25	68·4	87″	1·85	47	...	194	2 84
7-8	7·22	627·9	9·25	68·0	87″	1·54	56 5	...	150·5	2·86
8-9	7·22	583·0	9·25	63·2	87″	1·54	56 5	...	...	3 08
9-10	7·22	583·5	9 25	63·2	87″	1 54	56 5		...	3 08
10-11	7 22	582 3	9·25	63·1	87″	1 54	56 5	...		3 08
11-12	7·22	586·5	9 25	63·3	87″	1 54	56 5	...	...	3·08
12-13	7·22	568·7	9 25	61·4	87″	1 54	56 5	...	...	3·18
13-14	7·22	525·8	9 25	57·1	87″	1 54	56·5	...	...	3·5
14-15	7·22	549·0	9·25	59·3	87″	1 54	56 5	...		3·28
15-16	7 22	575·3	9 25	62·2	87″	1 54	56 5	...	...	3 13
16-17	7·22	555·8	9·25	60·1	87″	1·54	56 5	...	...	3·23
17-18	7·22	601 4	9·25	64·8	87″	1 54	56 5	...	...	3·0
18-19	7·22	597·6	9 25	64·6	87″	1·54	56 5	...	...	3 0
19-20	7 22	623·3	9·25	67·3	87″	1·54	56 5	...	...	2·89
20-21	7 22	620·0	9 25	67·0	87″	1 54	56 5	...	...	2 89
21-22	7·22	624·7	9 25	67·6	87″	1·54	56 5	...	...	2·87
22-23	7·22	625·6	9·25	67·7	87″	1·54	56 5	...	...	2 87

Table VIII

Stresses in the members of bottom boom.

Members.	Area (sq in.)	Moment (ft.-tons)	Distance (ft.)	Total Stresses in tons	l (in.)	r (in.)	l/r	Crippling Load according to Dorman Long's Hand Book: per sq inch	Crippling Load according to Dorman Long's Hand Book: Total	Factor of Safety.
1-2	...	...	Hinge							
2-3	8·72	729·8	8·4	86·8	50″	1·84	27·2	23·4	204	2·35
3-4	8·72	713·4	9·25	77·2	84″	1·84	45 7	22·4	195 5	2·53
4-5	8·72	720·4	9·25	77·8	84″	1·84	45·7	22·4	195·5	2·52
5-6	8·72	718·4	9·25	77·7	84″	1 54	45 7	22·4	195 5	2 5
6-7	8·72	728 4	9·25	78·8	84″	1·54	45·7	22·4	195·5	2·0
7-8	7·22	721·4	9·25	77·8	84″	1·54	54·5	21 8	157·5	2 0
8-9	7·22	729·4	9·25	78·8	84″	1·54	54·5	21 8	157·5	2·0
9-10	7·22	717·4	9·25	77·4	84″	1·54	54·5	21·8	157·5	2·0
10-11	7·22	706·4	9·25	76·4	84″	1·54	54·5	21·8	157·5	2·05
11-12	7·22	692·4	9·25	74·8	85″	1·54	55·2	21·7	157	2 1
12-13	7·22	682·1	9·25	73·7	85″	1·54	55·2	21·7	157	2·1
13-14	7·22	673·6	9·25	72·8	85″	1·54	55·2	21·7	157	2·15
14-15	7·22	672·6	9·25	72·7	85″	1·54	55·2	21·7	157	2·15
15-16	7·22	656·1	9·25	70·9	85″	1·54	55·2	21·7	157	2·2
16-17	7·22	642·3	9·25	69·4	86″	1·54	55·2	21·7	157	2·25
17-18	7·22	628·9	9·25	67·8	86″	1·54	55·8	21·7	157	2·3
18-19	7·22	611·7	9·25	66·2	86″	1·54	55·8	21·7	157	2·35
19-20	7·22	597·3	9·25	64·5	86″	1·54	55·8	21·7	157	2·4
20-21	7·22	589·4	9·25	63·7	86″	1·54	55·8	21·7	157	2·47
21-22	7·22	560·4	9·25	60·5	87″	1·54	56·4	21·6	156	2·55
22-23	7·22	561·4	9·25	60·6	87″	1·54	56·4	21·6	156	2·55

by giving increased suspension rods and necessary cross beams, a light guage track was then laid across the bridge so as to distribute the load and the hinge was pulled across by means of a crab winch fixed on the Kalimpong side. Due to the weight the hinges gave considerable trouble and in the author's opinion, for similar work, a built up steel hinge would be far more serviceable.

Erection of Centering.—Two double drum type Capstan winches were fixed on the shore spans and anchored to the bridge foundations. The erection of these winches on the Teesta side was simple as the approach spans were straight, on the Kalimpong side one was straight and two curved, consequently one winch overhung the roadway which necessitated a special platform. The two erection towers were fixed as close as possible to the river side end of the shore spans and consisted of 2 ins $\times$ 2 ins. $\times$ $\frac{1}{4}$ ins. angles connected together. A special seating (later cut away) was cast on the abutment to carry the cast iron hinges, these being held in position by 8 holding down bolts concreted into the abutment. In order to allow a certain amount of movement the bolts were placed inside thin steel tubes for a depth of three feet from the face of the abutment and after the hinges had been correctly adjusted, were grouted in. Owing to the weight of the hinges erection was troublesome as a crane could not be used for lifting them owing to the obstruction from the steel reinforcement for the arch rib. The small section was placed on the seating and bolted down, the larger section was then jacked up into its correct position and the pin driven home. The end section of the centering was then placed on a sleeper crib and bolted to the hinge, three 14 feet sections were cantilevered out from the end section and raised into their correct position by means of a wire rope fastened to the last section and connected to the winch.

Further sections were now cantilevered out and a second rope from the winch fastened to same, this process was continued until the two halves were connected together. All the ropes were fitted with turn-buckles at their lower ends connected to the centering, these being used to keep the correct tension in each rope. After the two halves had been connected the ropes were released and the centering allowed to take up its own position, the deflection, when the ropes were fully removed was 4 inches.

Method of Fixing the Lagging to the Centering.—Packing pieces were placed on the top boom at 7 feet centres to cover the bolts and give a seating to the wedges. On the packing strips 8 inch vertical wedges were placed, these having been designed to have a vertical movement of 4 inches. On the wedges 4 ins. × $1\frac{1}{2}$ ins. R.S. Joists, bent to the correct curvature of the arch were placed and on these joists 3 inch lagging was fixed to carry the concrete.

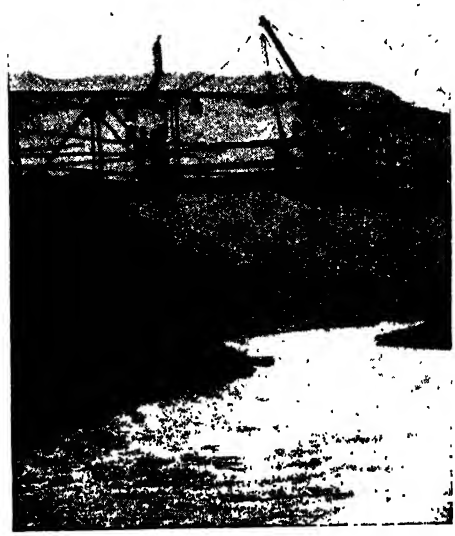


Fig. 6.—Steel centering being coupled up at the crown.

Method used to make certain that the shape of the arch should be exactly as designed after release of the centering.—As the shape of an arch plays a very important part in the design it is most essential that the shape is not altered due to deflection of the centering. Usually this is easy as the centering is erected from either solid ground or carried on piles and the only movement which can take place is that due to the compression of the members and closing of the various joints. In this case the centering being a two hinged steel arch deformation could easily take place unless steps are taken to prevent it. To do this the steel centering was loaded with sand to the same weight

as that of the arch rib, the sand being carried on bamboos placed on the bottom boom of the centering. The lagging could now be placed in the exact position as indicated on the drawings, any change in shape being impossible provided that the arch was symmetrically cast on the two sides and that a corresponding weight of sand was thrown into the river, thus keeping the weight constant.

Method of Releasing the Centering.—This was intended to be done by means of the vertical wedges, the bolts holding the two halves of the wedge together being loosened thus allowing the centering to fall without shock. This method was found to be impossible for the following reason, on checking the level of the centering at the crown after erection it was found to be 6 inches higher than the level given on the drawing, this being due to an error in the positioning of the hinges to carry the centering. The distance between the soffit of the concrete arch and the top of the centering was therefore insufficient to place this type of wedge. The vertical wedges were therefore replaced by horizontal ones at 7 feet centres. As, however these wedges had not a vertical movement of 4 inches, which amount was necessary in order to free the centering, some other method of lowering had to be devised. After discussion it was decided to reload the centering with sand, thus forcing it away from the concrete arch, this loading to be continued until the wedges were free. The latter, lagging, etc. were then removed and the centering allowed to rise to its unloaded position, it was found that the centering rose 3 inches on removal of the load. As already explained the factor of safety available in the centering was 2 and with the extra load was further reduced, the members, however, showed no signs of over-strain.

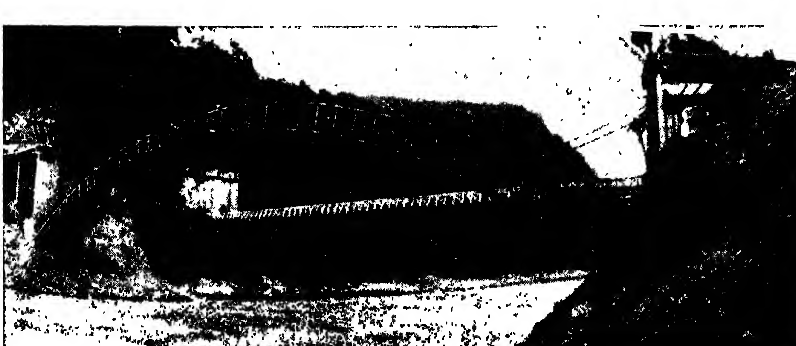
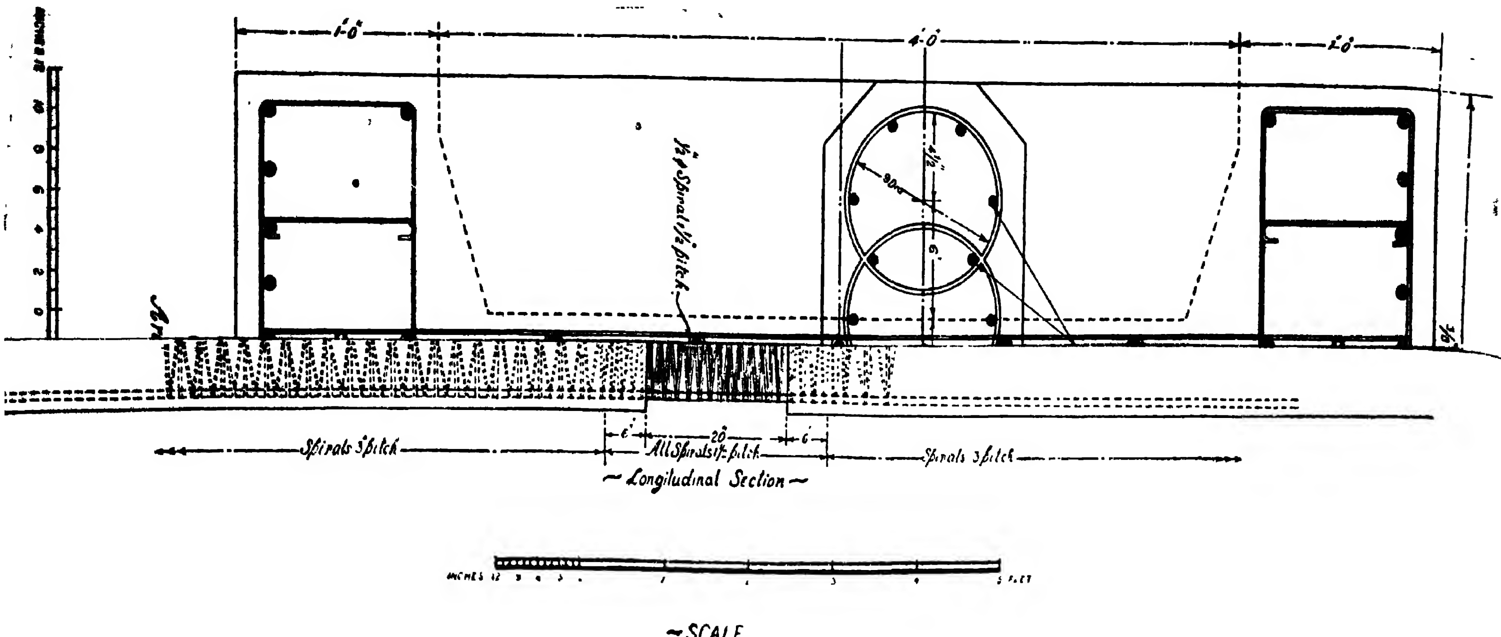


Fig. 7.

Plate XI.



DETAILS OF TEMPORARY HINGES
AT CROWN, TEESTA BRIDGE

Abstract of costs of centering, etc. (excluding supervision and profit.)

Materials	I	(a) Steel centering	... ...	13,117/-
		(b) Hinges	... ...	4884/-
	II	Erection towers complete with head-gear	...	2218/-
	III	Erection tackle including crab winches ...	...	7596/-
	IV	Materials for winch erection	... ...	600/-
Freight		Railway freight on items I, II and III	... ...	4100/-
		Freight from station to site	... ...	960/-
Labour		Lowering and fixing hinges	... ...	418/-
		Fixing crab winches ...	... ...	418/-
		Erection of centering	... ...	2231/-
		Tightening bolts	... ...	166/-
				36,708/
			say ...	37,000/-

Temporary Hinges.—The following effects produce shortening or similar effects in an arch member.

1. Shrinkage of concrete during setting and hardening
2. Elastic compression in arch rib due to superimposed load.
3. Settlement of abutments under arch thrust.

In a hingeless arch this shortening produces bending moments which permanently stress the arch. If hinges are introduced at the springings and the crown the arch can freely

Fig. 8.—Showing reinforcement for temporary hinge at springing.

accommodate, without appreciable strain, any slight alteration in length by a rise or fall of the crown. Furthermore, this shortening is produced for the most part during construction, since—

1. Most of the Shrinkage takes place during this period.
2. In most arch bridges the weight of the superstructure is much greater than the total superimposed moving loads coming on the bridge.

It is principally with the object of eliminating these stresses produced by the arch shortening that temporary hinges are introduced.

Description of Temporary Hinges at Springing.—The hinge has a cross sectional area of 468 square inches and is reinforced with 4 interlocking spirals having a mean diamater of 11½ inches with a pitch of 2¼ inches; diameter of spiral iron ½ inch. The longitudinal reinforcement consists of 20 bars ⅝ inch. diameter (for details see Plate XI).

Description of Temporary Hinge at the Crown.—The hinge has a cross sectional area of 414 square inches and is reinforced with 5 interlocking spirals having a mean diameter of 9⅜ inches with a pitch of 1½ inches; diameter of spiral iron ⅜ inches. The longitudinal reinforcement consists of 24 bars ½ inch diameter, (for detail see Plate XI).

Concrete of the Arch Rib.—The aggregate consisted of broken boulders, carefully selected, from local jhoras. They were machine crushed to the following sizes—¾ inch, ½ inch and ¼ inch, the aggregate being graded to conform as closely as possible to the Fuller Curve. The following mixture was used for the shore spans 110½ lbs. (=1 bag) cement, 2½ cubic feet sand, 1·33 cubic feet ¾ inch stone, 1·33 cubic feet ½ inch stone and 1 cubic foot ¼ inch stone. This concrete gave an average crushing strength of 3,600 lbs. per square inch at 28 days with a 6 inch slump. The above mix was designed to give 4,000 lbs. per square inch and as the specimens had been made from unwashed aggregate it was decided to make further tests using washed aggregate in order to see what effect clean materials had. The average crushing strength with washed materials was 4,300 lbs. per square inch thus proving that clean materials are essential for good and consistent concrete. In order to fix a suitable mix for the arch rib the following was tested—110½ lbs. cement. 1·75 cubic feet sand, 1·2 cubic feet ¾ inch stone, 1·2 cubic feet ½ inch stone and 0·6 cubic foot ¼ inch stone, this mix with 4½ inch slump gave a crushing strength of 5,953 lbs. per square inch, as this was greater than specified the following mix was tested. 110½ lbs. cement, 2 cubic feet sand, 1·25 cubic feet ¾ inch stone, 1·25 cubic feet ½ inch stone and 0·75 cubic foot ¾ inch stone, this with 4¼ inch slump gave an average strength of 5,600 lbs. per square inch at 28 days and was the mix used in the arch rib. Owing to the close

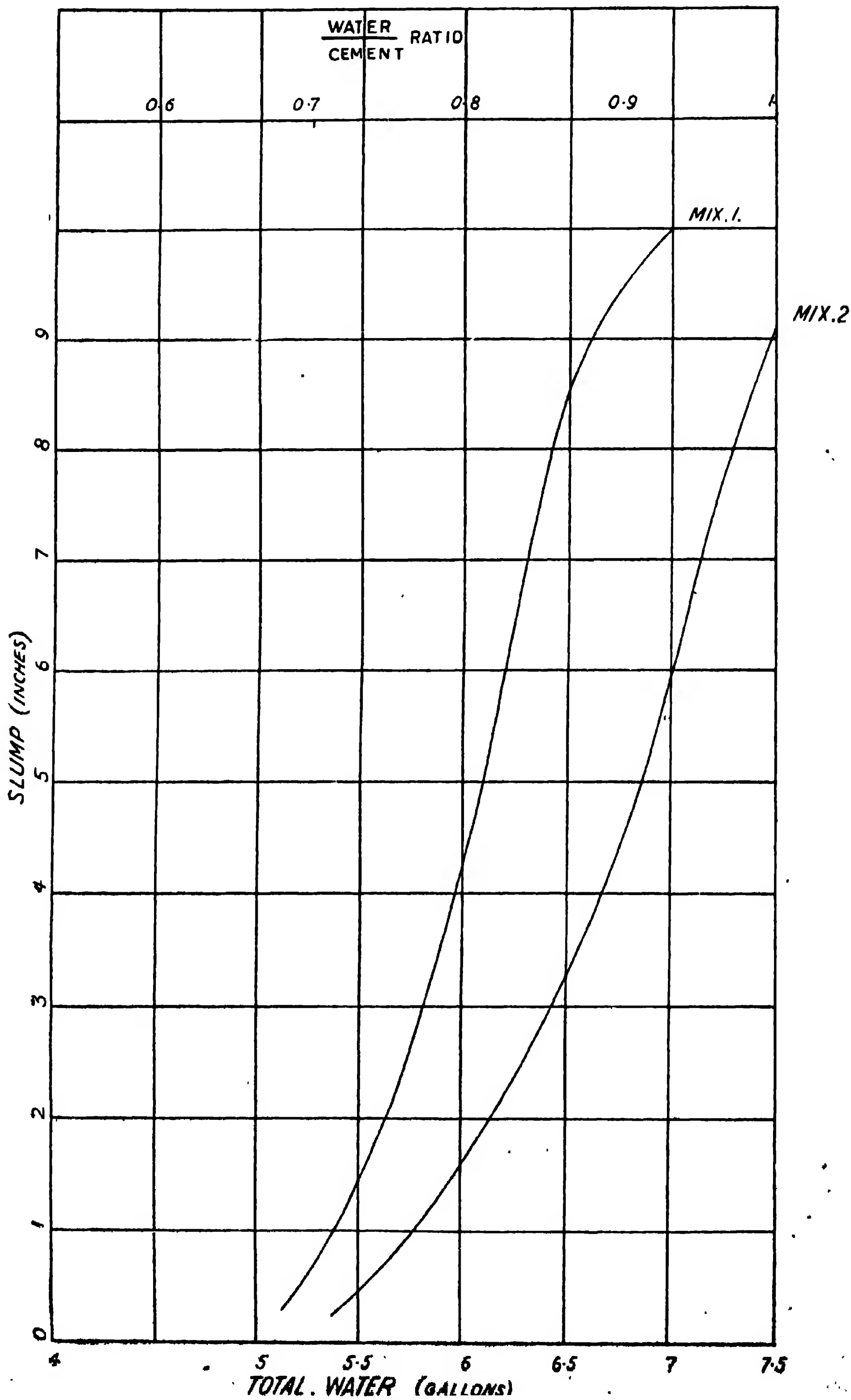
spacing of the steel in the rib the question of what slump was to be used became important. A sample rib was made and it was found that the concrete could be placed with a slump of 4½ to 5 inches, however on casting the rib section in the abutments it was found that in order to get the concrete in position a minimum slump of 6 inches was necessary. As the contractors objected to this slump tests were carried out with the materials to be used. The materials were carefully dried and then mixed, water being added in definite quantities and the slump measured, the curves on page 282 show the results for mixes used in (1) arch rib and (2) approach bridge.

From curve 1. it will be seen that a slight increase in water alters the slump considerably—

⅛ gallon of water increases the slump from 6·65-7 72 inches
¼ gallon ,, ,, ,, ,, 6·65-8·55 inches
½ gallon ,, ,, ,, ,, 4·85-8 55 inches

It is a well-established fact that provided the raw material both as regards proportions, grading, cleanliness, etc., are constant the strength of the resultant concrete depends to a very large extent upon the water-cement ratio. From curve 1, it is seen that with a slump variation between 4·35 and 8·55 inches the water-cement ratio only varies from 0·8 to 0·867. As the water-slump curve varies with different aggregates, grading, etc., the Author considers that a curve of this type should be drawn immediately the materials to be used on the construction have been settled. When casting the arch rib it was seen that a slump of 6 inches was absolutely essential and that a slump of 6-7½ inches, measured on platform below chute, made placing fairly easy. It was also noticed that the slump as measured on concrete entering the casing can vary by 2—2½ inches from that measured at the mixer and by 1—1½ inches if measured on mixing platform, depending on the distance carried, time taken to place and rate of evaporation. The bulking effect of wet sand must be carefully taken into account otherwise the quantities of sand given in the mixes mentioned above will be far too small and the result will be a harsh mix.

The arch rib was concreted in sections as shown in fig. B on page 313, this being done so as to reduce the contraction stresses to a minimum. Sand was thrown into the river as the concrete was deposited thus keeping the load on the centering constant. Timber shuttering was used at the ends of the sections, after



WATER / CEMENT RATIO
0·6
0·7
0·8
0·9
MIX. 1.
MIX. 2
SLUMP (INCHES)
0
1
2
3
4
5
6
7
8
9
4
5
5·5
6
6·5
7
7·5
TOTAL. WATER (GALLONS)

removal of this shuttering the concrete was hacked and before adjoining concrete was placed it was coated with cement grout. The concrete was machine mixed, the mixer being placed on the end of the shore span, and was conveyed by a chute to a platform between the two ribs, it was then carried by coolie and deposited in the forms. This process was slow and as already explained the slump varied very considerably between that measured at the mixer and that measured as the concrete was going into the forms. The formwork was hammered during deposition so as to free as much air as possible. Only a short section of the stiffener adjoining the rib was cast with the rib, it being considered advisable to release the centering before finally closing the stiffeners thus avoiding cracks should the two ribs settle unequally. The concreting gave no trouble and was completed in 10 days. After casting, the concrete was kept wet for ten days and the centering released when the last placed concrete was 28 days old. The average crushing strength of the concrete at 28 days was 4,500 lbs. per square inch cured under working conditions.

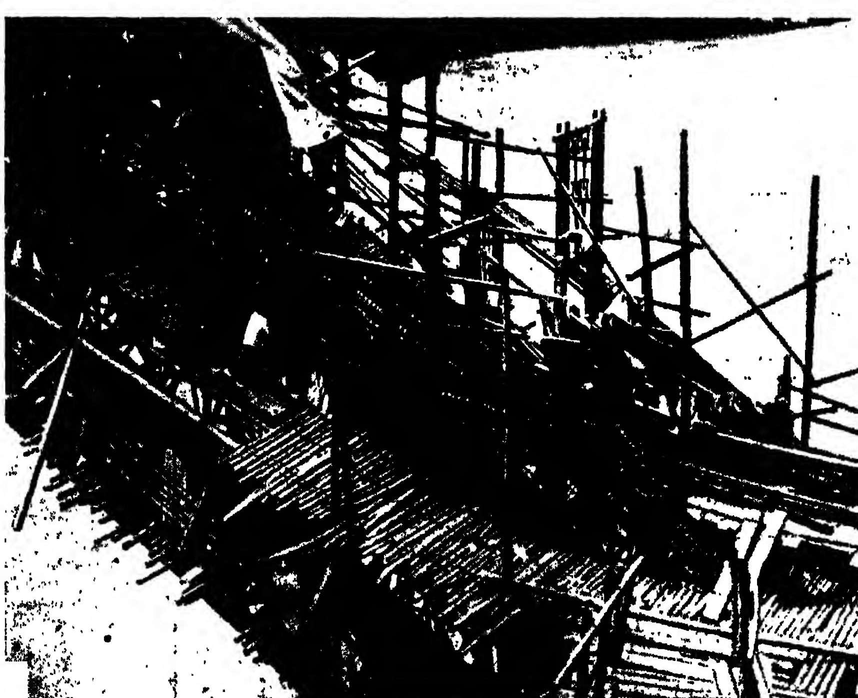


Fig. 9—Placing of steel in progress.

One point should be carefully noted when casting ribs of this type and that is — the column footing must be cast along with the arch rib, otherwise it is very difficult to fix the column shuttering. This omission at Teesta not only caused delay but also an increase in the size of columns supporting the roadway as during the concreting of the arch ribs the column bars were used as hand rails by the workmen walking along the lagging to the arch, due to this they were displaced and in order to obtain adequate cover to the displaced bars the size of column had to be increased from 17×17 inches to 18×18 inches.

Details of cost re: concrete in arch ribs including bracings between ribs (excluding profit and supervision.)

	Labour Rs.	Material Rs.	Total Rs.
1. Making and fixing wedges ...	521	1500	2021
2. Bending and fixing R.S. Joists to carry lagging	85	550	635
3. Fixing packing, lagging, etc. ...	1287	2554	3841
4. Rib reinforcement including portion in abutment	3339	17,730	21,069
5. Casing to rib	2147	4175	6332
6. Alteration to casing	2469	...	2469
7. Dismantling casing	257	...	257
8. Casting concrete for ribs ...	1168	8036	9204
9. Loading and unloading steel centering	297	...	297
10. Curing ribs	267	...	267
11. Lowering centering	183	...	183
12. Miscellaneous items	601	...	601
13. Rectifying defects in arch rib after casting	1049	357	1406
14. Carriage and repairs of tools and plant	164	...	164
15. Bracings between ribs ... Reinforcement	141	670	811
Shuttering	759	135	894
Concrete	184	1491	1675
Total ...	14,918	37,198	52,116

Total volume of concrete in arch ribs and bracings is 8,518 cubic feet. Therefore cost per cubic foot=Rs. 6·118/-.

Control of Quality of Concrete.—Each batch of cement was tested and the results recorded on form 1. Grading tests, beams tests and cylindrical test specimens were taken daily when concreting was in progress and details recorded on forms II, III and IIIb.

As no compression testing machine was available at site a beam testing machine was made, and was used to obtain results on trial mixes.

1. ***Testing Concrete by Means of Beams.***—Preparation of test beams, for details see pages 286 and 287. The beam forms should be well wetted before filling with concrete. During the placing of the concrete the correct position of the steel must be carefully maintained and this is done by placing the steel directly on the form. The concrete is to be prepared in exactly similar conditions to those employed on the construction and as soon as the concrete had set a little the top surface should be struck off smooth.

2. ***Testing the Beams.***—The test beams are to be destroyed by bending and are so proportioned that the bending strength of the concrete is overcome by the test load. According to up-to-date experience the concrete possesses sufficient compressive strength if the bending compressive strength of the test beams amounts to 1·37 times that of 12 inches by 6 inches cylindrical test specimens when calculated according to the usual theory. The test beam is loaded with two point loads P/2 on an 80 inches span, the point load acting 4 inches from the centre of the beam, see diagram on page 286.

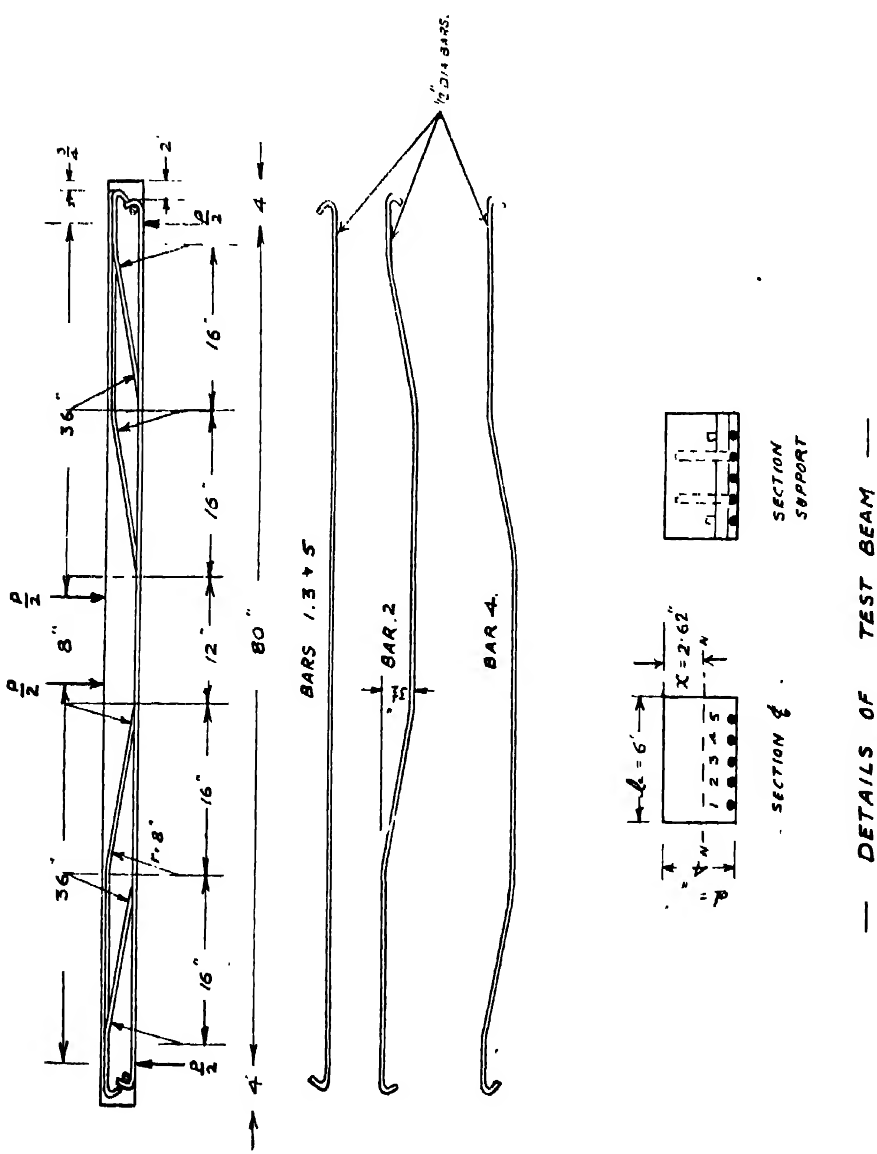
During testing special attention is to be paid to seeing that the beam is correctly positioned. The load should be increased slowly and without shock until the beam breaks. The maximum load shown on the manometer, when after pumping no increase is shown, is to be taken as the breaking load. The relationship between the pressure P tons per square inch, shown on the manometer and the bending compressive strength of the beam, for the type of beam used at Teesta is

$$\sigma_b \text{ lb/sq. in.} = 5600\,P + 141$$

(for derivation of formula see pages 287 and 288).

Tests on cylinders and beams made from the same batch of concrete gave the following results—cylinder crushing strength

(Alipore Test House) 3,750 lbs. per square inch and beam crushing strength 5,140 lbs. per square inch *i.e.*, a ratio of 1: 1·37. The mix for the above test was 221 lbs. cement, 2·67 cu. feet ¾ inch stone, 2·67 cu. feet ½ inch stone, 2 cu. feet ¼ inch stone, 5 cu. feet sand with a 4 inch slump.



Details of Test Beam

$b = 6''$

$d = 4'' \qquad h = 4 - 0{\cdot}25 = 3{\cdot}75''$

$f_e = 5\phi\frac{1}{2}'' = 0{\cdot}9815$ sq. inches

$$x = \frac{nF_e}{b}\left[-1 + \sqrt{1 + \frac{2\,bh}{nF_e}}\right]$$

$$= \frac{15 \times {\cdot}9815}{6}\left[-1 + \sqrt{1 + \frac{2 \times 6 \times {\cdot}375}{15 \times {\cdot}9815}}\right]$$

$$= 2{\cdot}4537\left[-1 + \sqrt{1 + 3{\cdot}06}\right]$$

$$= 2{\cdot}4587 \times 1{\cdot}035$$

$$= 2{\cdot}62 \text{ inches}$$

Let P = pressure of gauge in tons

Diameter of piston = 2 inches

$\therefore$ Load on beam $= 0{\cdot}7854 \times 4 \times P$

$= 3{\cdot}1416\,P$ tons.

Bending moment due to this load

$$= M_p = \frac{3{\cdot}1416\,P}{2} \times 36 = 56{\cdot}55\,P \text{ inch-tons}$$

Bending moment due to dead load

$$M_g = \left.\begin{array}{l}\text{Moment due to}\\ \text{weight of beam}\end{array}\right\} + \left\{\begin{array}{l}\text{Moment due to}\\ \text{wt. of cylinder gauge, etc.}\end{array}\right.$$

$$= 150 \times \frac{80}{12} \cdot \tfrac{1}{2} \cdot \tfrac{1}{2} \cdot \frac{80}{8} + \tfrac{1}{2} \times 85 \times 36$$

$$= 1665 + 1530 = 3195 \text{ inch-lbs.}$$

$$M_q = M_p + M_g$$

$$= 56{\cdot}55 \times 2240P + 3195 \text{ inch-lbs.}$$

$$Z = h - \frac{X}{3}$$

$$= 3{\cdot}75 - 0{\cdot}87 = 2{\cdot}88''.$$

We have the following relationship

$$\sigma_b \cdot \frac{bx}{2} \cdot Z = M_p + M_g$$

$$\text{now } \frac{bx}{2} \cdot Z = \frac{6 \times 2{\cdot}62 \times 2{\cdot}88}{2} = 22{\cdot}61$$

$$\therefore \quad \sigma_b = \frac{M_p}{22{\cdot}61} + \frac{M_g}{22{\cdot}61}$$

$$= \frac{56.55 \times 2240.P}{22{\cdot}61} + \frac{3195}{22{\cdot}61}$$

$$= (5600\ P + 141) \text{ lbs. per square inch.}$$

Stress in steel if concrete breaks at 4000 lbs. per square inch ($P = 0{\cdot}689$ tons per square inch.)

$$= \frac{M_q}{F_e\ Z}$$

$$= \frac{M_q}{{\cdot}9815 \times 2{\cdot}88} = \frac{M_q}{2{\cdot}822}$$

$$= \frac{56{\cdot}55 \times 2240\ P}{2{\cdot}822} + \frac{3195}{2{\cdot}822}$$

$$= 45000\ P + 1131.$$

$$= 45000 \times 0{\cdot}689 + 1131$$

$$= 32131 \text{ lbs. per square inch.}$$

It is therefore evident that for the particular specimen, assuming that the concrete is crushed at 400 lbs. per inch square, the stress in the steel would exceed the elastic limit long before the utlimate failure of concrete. As soon as this happens Young's modulus can no longer be regarded to hold good and the calculations of stresses according to the standard formulae will give slightly erroneous results. It would have been therefore better to increase the steel in the specimen so that at the crushing load of concrete the stress in the steel would still be within the elastic limit.

Superstructure.—The columns and beams supporting the roadway were designed as a rigid frame, the lower ends of the columns being assumed fixed. The points of contra-flexure having been calculated, combined bending moment and shear diagrams were drawn for both beams and columns and the various members reinforced accordingly. The slab was covered with bitumen before the filling concrete and road surface were laid so as to waterproof the structural portion (see plates viii & x).

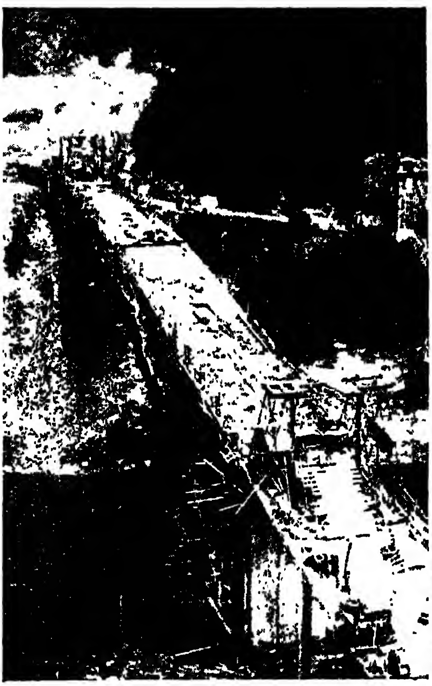


Fig. 10—Bridge nearing completion.

Fig. 11—Showing arch bracings.

Expansion joints were provided and filled with bitumen. The expansion joints in parapet and wheelguard consisted of "U" shaped copper strips.

Actual observed costs, excluding supervision and profit, for the columns and bracings of the main bridge.

Shuttering per cubic foot of concrete

Labour	...	1·66/-
Materials	...	0·65/-
		2·31/-

Concrete per cubic foot

Labour	...	0·195/-
Materials	...	1·005/-
		1·20/-

Reinforcement per cubic foot of concrete

Labour	...	0·528/-
Steel	...	2·320/-
Wire	...	0·049/-
		2·879/-

Miscellaneous, rectifying defects, curing, etc. per cubic foot
0·43/-

Therefore the total cost of reinforced concrete in column and bracings per cubic foot 6·84/-.

Actual observed costs for beams and slab of main bridge.

Shuttering per cubic foot of concrete

Labour	...	0·71/-
Materials	...	0·42/-
Dismantling	...	0·04/-
		1·17/-

Reinforcement per cubic foot of concrete

Labour	...	0·153/-
Steel	...	0·740/-
Wire	...	0·044/-
		0·91/-

Concrete per cubic foot

Labour	...	0·076/-
Materials	...	1·030/-
Carriage of aggregate, etc.	...	0·044/-
		1·150/-

Miscellaneous per cubic foot
0·03/-

Therefore cost of reinforced concrete in main beams and slab per cubic foot 3·26/-.

The large difference between the cost of concrete in the columns and bracings and the roadway slab, etc., was partially due to the contractors trying to use old timber for the columns, this is clearly seen from the labour costs. Timber of first class quality may be used several times but local timber warps to such an extent that re-use is sometimes more expensive than new timber, it should be remembered that the cost of local timber at site was only 12 annas per cubic ft. a further reason has already been given on page 283.

Testing the Bridge on Completion.—The arch was loaded with a uniform load of 84 lbs. per square foot by placing sand to a definite depth. The loading commenced on the Kalimpong side and was gradually extended to the Teesta side. Deflection readings were taken during loading and are given in table IX. In addition to the uniformly distributed load an additional crowd load, estimated at 15 tons, was placed at the crown. This additional load produced a deflection of 1/12 inch which immediately disappeared when the additional load was removed. The test was carried out in the presence of the Chief Engineer P.W.D., Superintending Engineer, Northern Circle and a representative of Messrs. Bird and Co., who were the contractors. A few days after the loading test observations regarding movement of the arch rib due to temperature were taken and are given in table X.

Fig. 12—A view of the completed bridge with the old suspension bridge in the foreground.

Fig 13—Another view of the Bridge

Arch Design

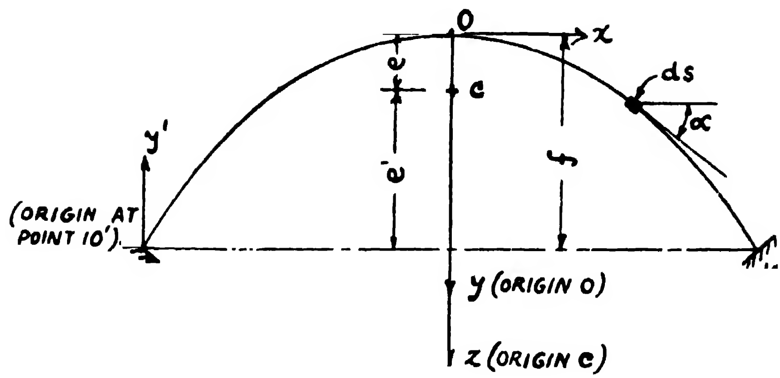


Fig. 36

Let c represent the elastic centre of the arch, that is to say the centre of gravity of all equal elements "*ds*" which are supposed to have masses equal to the inverse of the moment of inertia of the arch at the point considered. Let F and J represent respectively the plane area and the moment of inertia of the transverse section normal to the neutral axis.

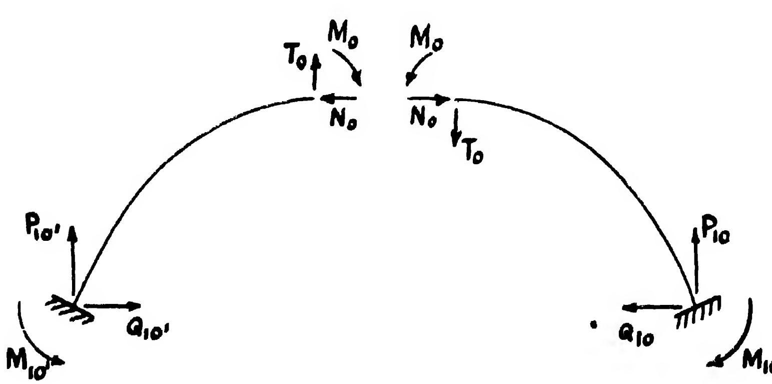


Fig. 37

The reactions at the springings will be represented by the letters P_{10}, Q_{10}, M_{10}, P_{10}, Q_{10}, and M_{10}; the elements M, N and T to be used and when the arch is cut at the crown will be represented by M_0, N_0 and T_0.

Influence Lines for M_o, N_o and T_o. The equations of these lines are given below

$$t_o = \frac{X \int_x^{\frac{l}{2}} \frac{X}{J}\, ds. - \int_x^{\frac{l}{2}} \frac{X^2}{J}\, ds.}{\int_{-\frac{l}{2}}^{+\frac{l}{2}} \frac{X^2}{J}\, ds.}$$

$$n_o = \frac{X \int_x^{\frac{l}{2}} \frac{Z}{J}\, ds. - \int_x^{\frac{l}{2}} \frac{XZ}{J}\, ds.}{\int_{-\frac{l}{2}}^{+\frac{l}{2}} \frac{Z^2}{J}\, ds. + \int_{-\frac{l}{2}}^{+\frac{l}{2}} \frac{\cos^2\alpha}{F}\, ds.}$$

$$m_o = (f-e') + \frac{X \int_x^{\frac{l}{2}} \frac{1}{J}\, ds. - \int_x^{\frac{l}{2}} \frac{X}{J}\, ds.}{\int_{-\frac{l}{2}}^{+\frac{l}{2}} \frac{1}{J}\, ds.}$$

in the above formulae,

$$e' = \frac{\int_{-\frac{l}{2}}^{+\frac{l}{2}} \frac{Y'}{J}\, ds.}{\int_{-\frac{l}{2}}^{+\frac{l}{2}} \frac{1}{J}\, ds.}$$

and $Z = e' - y'$.

Influence Lines for M, N and T at any point whatsoever and their reactions. These lines are deduced from their relation to the crown by calculation from simple statics. Below the formulae are given for a point on the semi arch to the right having co-ordinates X, Y and the angle α .

$$t = t_o \cos\alpha - n_o \sin\alpha + \ldots\ldots\ldots\ldots \cos\alpha$$

$$n = t_o \sin\alpha + n_o \cos\alpha + \ldots\ldots\ldots\ldots \sin\alpha$$

$$m = m_o + t_o X - n_o (f - y') + \ldots\ldots\ldots\ldots (X - x)$$

The terms cos α , sin α and (X—x) enter only for the abscissae between O and X. It must be remembered when applying these formulae that t_o and sin α change sign with x.

Influence Lines for the Reactions at Point 10.—From statics we have the following equations,

$$p_{10} = t_o + \ldots\ldots\ldots\ldots 1$$

$$q_{10} = n_o$$

$$m_{10} = t_o \frac{l}{2} - n_o f + m_o + \ldots\ldots\ldots\ldots \left(\frac{l}{2} - x\right)$$

The terms 1 and $\left(\frac{l}{2} - x\right)$ enter only for x > 0. Nor should it be forgotten when applying these formulae that t_o changes along with x.

Effects of Variation in Temperature.—The following formulae give the moment and thrust produced at the crown for a variation of t degrees.

$$N_{ot} = \frac{E.\beta.t.l.}{\int_{-\frac{l}{2}}^{+\frac{l}{2}} \frac{Z^2}{J}\, ds + \int_{-\frac{l}{2}}^{+\frac{l}{2}} \frac{\cos^2\alpha}{F}\, ds.}$$

$$M_{ot} = N_{ot}\ (f - e').$$

In the above formulae β is the coefficient of thermal expansion of the material of which the arch is constructed, in this case reinforced concrete.

At any point on the arch we have—

$$M_t = -\ N_{ot} Z$$

The moments produced in the arch rib due to a variation in temperature of 40 degrees Fahrenheit have been calculated and are tabulated in table XI.

Values of the influence line ordinates for various sections are given in tabular form in table XII and plotted on pages 299, 300 and 301. The position of the load to produce either maximum bending moment or maximum shear can easily be found on reference to the influence lines and has been tabulated on

pages 302 to 309. The maximum stress at any section is easily calculated when the maximum moment and corresponding thrust is known.

$$\sigma = \frac{N}{F} \pm \frac{M.y}{J}$$

In addition to the above we have to consider the stresses produced by a change in temperature,

$$\sigma_t = \frac{N_{ot}}{F} \pm \frac{M_{ot}\, y}{J}$$

The values of the maximum moments, thrust, etc. have been tabulated in tables XIII & XIV and the maximum stresses produced are in table XV. As the maximum stresses were above the permissible they were reduced by using rectangular spirals.

Table—XI

$$N_{o.t} = \frac{128571 \times 0{\cdot}000006 \times 40 \times 300}{2 \times 0{\cdot}0161 \times 2670{\cdot}5 \times 16{\cdot}15}$$

$$= 6{\cdot}52 \text{ tons.}$$

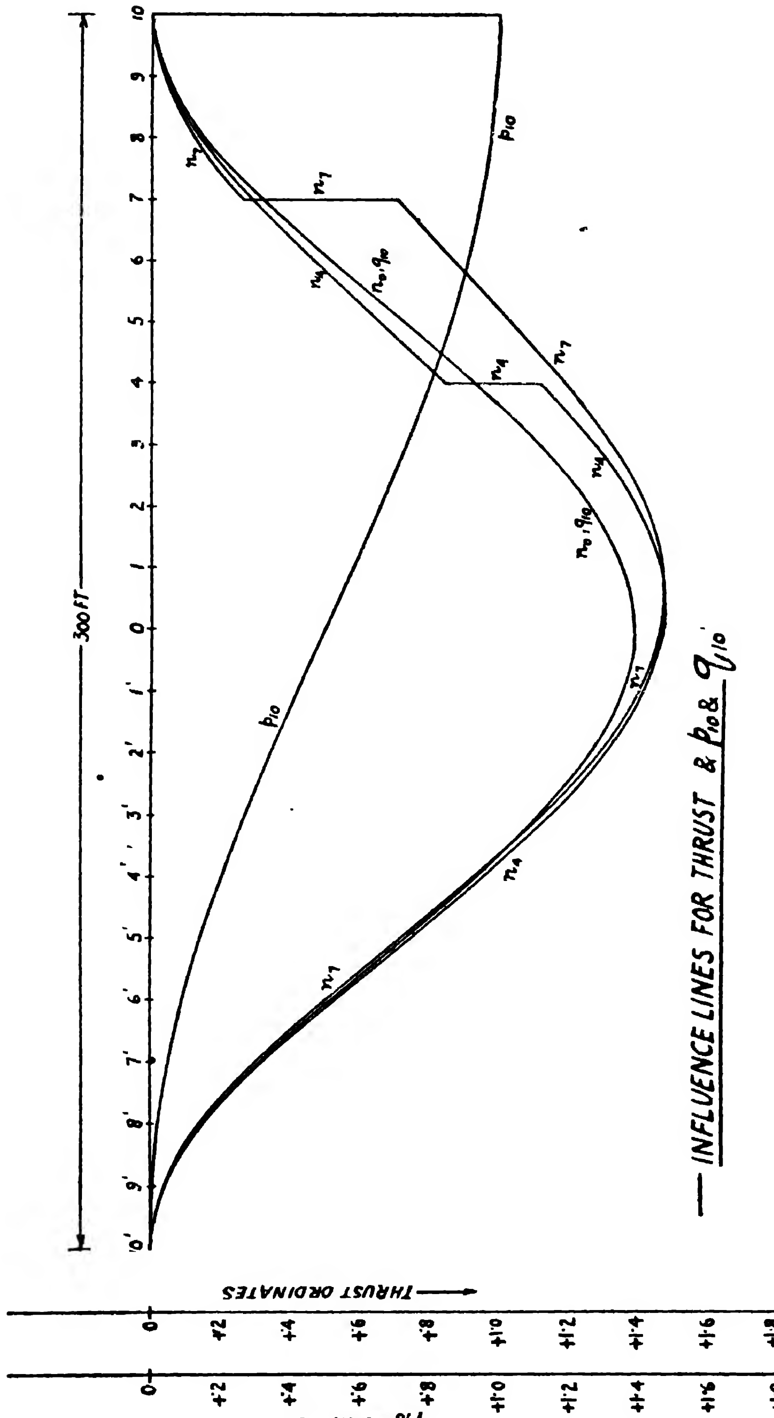
Point	Z—(l'-y') ft.	$N_{o\ t}$ tons.	Moment ft. tons
0	−16·035	+6 52	— + 104·60
1	−15·535	,,	— + 100·10
2	—14·205	,,	— + 92·60
3	11·455	,,	— + 74 70
4	−7·655	,,	— + 49·90
5	2·825	,,	— + 18 41
6	+2·795	,,	+ — 18·23
7	9 465	,,	+ — 61 78
8	16·885	,,	+ —110·01
9	25·095	,,	+ —169·28
10	33·965	,,	+ —221·60

Note.—Lower values denote moments due to increase in temperature of 40° F.

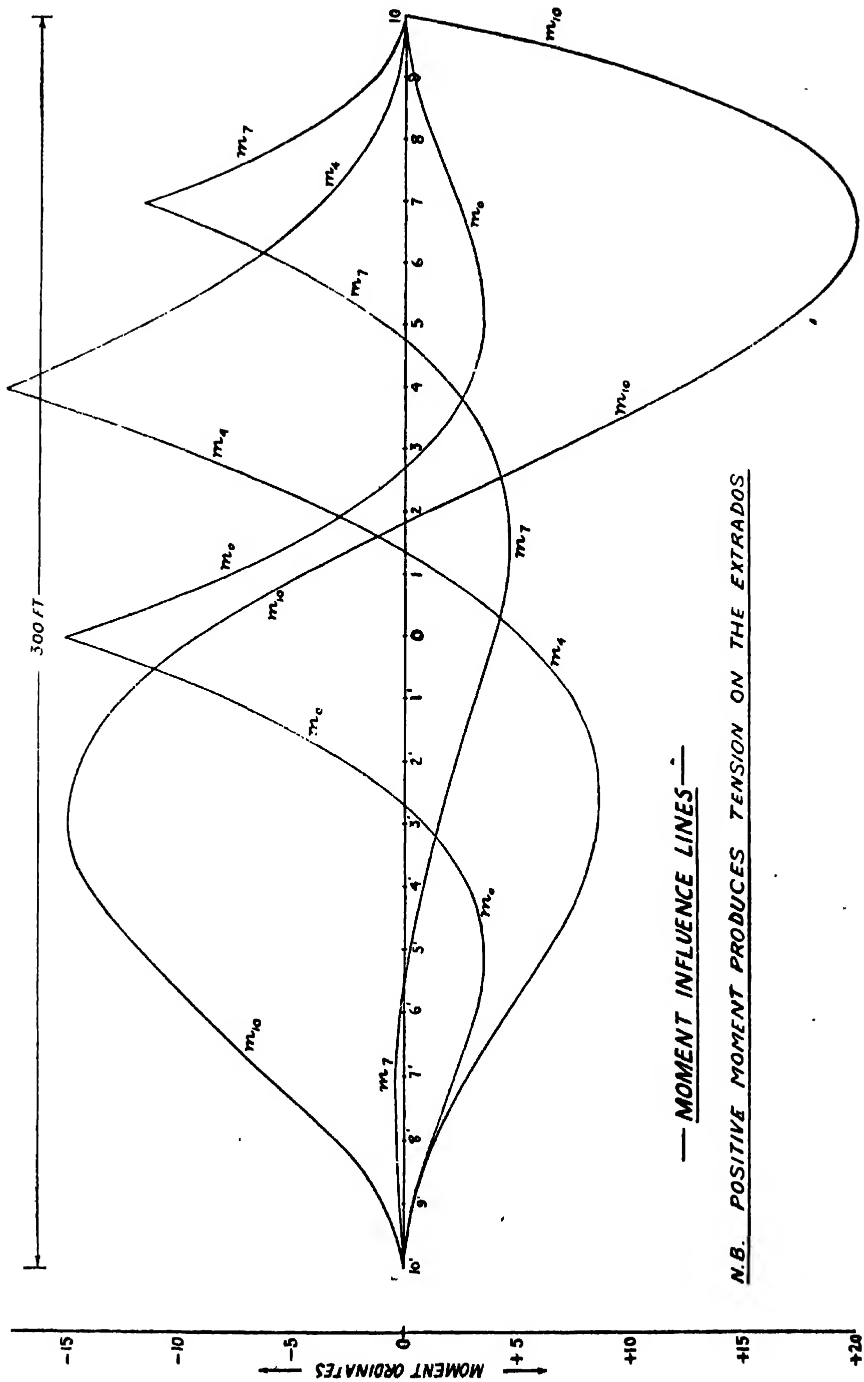
Table—XII

Influence Line Ordinates.

POINT.	CROWN.			SECTION 4. 60 ft. from Crown.			SECTION 7. 105 ft. from Crown.			SPRINGING.		
	t_0	n_0	m_0	t_4	n_4	m_4	t_7	n_7	m_7	P_{10}	q_{10}	M_{10}
10	0	0	0	0	0	0	0	0	0	1·000	0	0
9	−·00558	0·419	+0·3742	−·01701	·0348	−·03309	−·0237	0·0350	−1·2968	·9944	·0419	+10·862
8	−·0231	·1543	+1·261	−·0661	·1417	−1·497	−·0893	·1279	−5·1731	·9769	·1543	17·421
7	−·0519	·3206	+2·160	−·1389	·2931	−3·813	−·1893 +·7058	·2637 ·7096	−11·623	·9481	·3206	19·965
6	−·0918	·5195	+3·188	−·2327	·4725	−6·985	+·5812	·8700	−5·317	·9082	·5195	19·733
5	−·1430	·7310	+3·509	−·3405	·6619	−11·684	+·4413	1·036	−0·961	·8570	·731	16·779
4	−·2006	·9360	+ ·2790	−·4531 +·5074	0·8424 ·1206	−17·751	·2989	1·1945	2·140	·7994	·936	12·440
3	−·2681	1·119	+0·92	+·3923	1·2777	−9·87	·1566	1·3264	3·82	·7319	1·119	6·895
2	−·3418	1·262	−2·60	·2819	1·3941	−3·392	·0269	1·4205	4·54	·6582	1·262	1·03
1	−·4195	1·353	−7·80	·1812	1·4616	+1·64	−·0834	1·4700	4·57	·5805	1·353	+4·465
0	−·5000 +·5000	1·383	−15·09	·0953	1·4681	+5·05	−·1681	1·4511	3·59	0·500	1·383	−9·240
1′	+.4195	1·353	−7·80	+·0263	1·4166	+7·47	−·2275	1·3979	3·12	0·4195	1·353	−12·525
2′	+·3418	1·262	−2·60	−·0284	1·3061	+8·508	−·2560	1·2844	2·26	·3418	1·262	−14·43
3′	+·2681	1·119	+0·92	−·0538	1·1485	8·57	−·2585	1·1195	1·50	·2681	1·119	−14·815
4′	+·2006	·9360	+2·790	−·0689	0·9536	7·65	−·2380	·9270	0 60	·2006	0·936	−13·92
5′	+·1430	·7310	+3·509	−·0659	0·7413	6·46	−·1978	·7170	0·349	·1430	·731	−11·591
6′	+·0918	·5195	+3·188	−·0563	0·5245	4·659	−·1491	·5059	−0·097	·0918	·5195	− 9·017
7′	+·0519	·3206	+2·160	−·0392	0·3219	2·769	−·0965	·3099	−0·381	·0519	·3206	− 6·085
8′	+·0231	·1543	+1·261	−·0217	0·1545	1·433	−·0482	·1485	−0·169	·0231	·1543	− 2·989
9′	+·00558	·0419	+0·3742	−·00629	0·0417	0·3773	−·0138	·03998	−0·088	·00558	0·419	− 0·884
10′	0	0	0	0	0	0	0	0	0	0	0	0

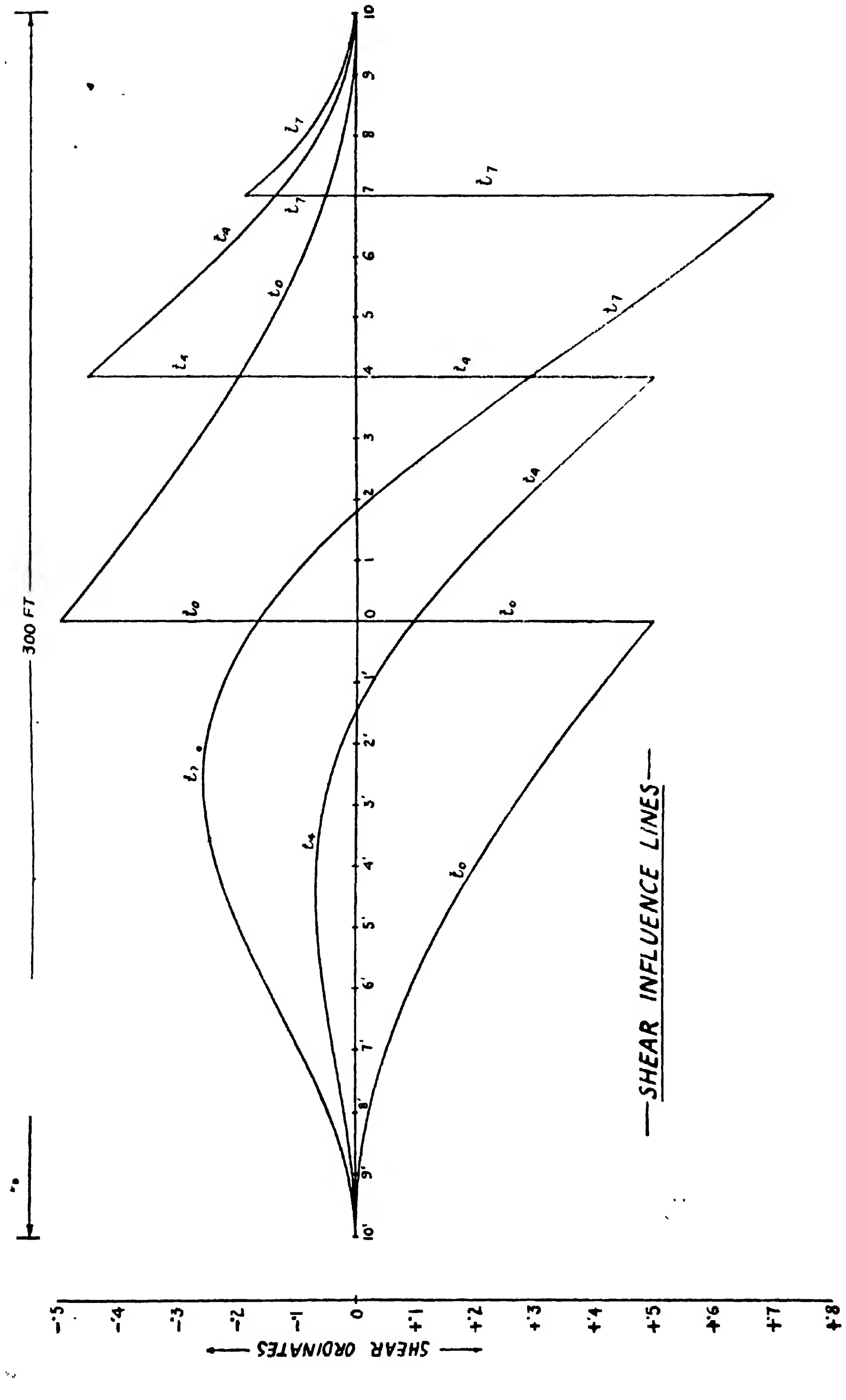


INFLUENCE LINES FOR THRUST & p_{10} & q_{10}



— MOMENT INFLUENCE LINES —

N.B. POSITIVE MOMENT PRODUCES TENSION ON THE EXTRADOS


SHEAR INFLUENCE LINES
300 FT
SHEAR ORDINATES
-·5
-·4
-·3
-·2
-·1
0
+·1
+·2
+·3
+·4
+·5
+·6
+·7
+·8
10
9
8
7
6
5
4
3
2
1
0
1'
2'
3'
4'
5'
6'
7'
8'
9'
10'
t_0
t_4
t_7

Position of loading on roadway to give maximum moments in different sections of arch rib taken from B.M. influence line diagrams for arch rib.

Section at which moment is to be considered	Sign of B.M.	Details of loading
Crown (0)	Positive	(a) Two hind wheels of a 10 ton roller at 75'-0" (left) of the span from crown total weight 9·80 tons. (b) 1 front wheel of a 10 ton roller at 85·67 (left) of the span from crown total weight 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 92·83 to 150 and 43' to 67·84' ft. (left of crown) (d) ·337 tons ft. run of bridge distributed from 43' to 150' to right of crown.
	Negative	(a) 2 hind wheels giving a load of 9·8 tons at centre. (b) 1 front wheel giving a load of 4·90 tons 10·67' left. (c) ·337 tons ft. run of bridge distributed from 17·83' to 43'-0" left. (d) ·337 tons ft. run of bridge distributed from 7·16 ft. to 43'-0" right.
1 (15"-0")	Positive	(a) 2 hind wheels at 60' right total weight 9·80 tons. (b) 1 fore wheel at 70·67' right total weight 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 77·83' to 150' right, and 52·84 to 23'-0" right of crown. (d) ·337 tons ft. run of bridge distributed from 67'-0" to 150' left of crown.
	Negative	(a) 2 hind wheels at 15' left wt. 9·80 tons. (b) 1 fore wheel at 25·67' left wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 32·83 ft. left to 150', and 7·84 left to 32'-0" right. (d)
2 (30'-0")	Positive	(a) 2 hind wheels at 60'-0" right wt. 9·80 tons. (b) 1 fore wheel at 49·33' right wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 42·17' right to 6·4' right and 67·16' right to 150' right. (d) ·337 tons ft. run of bridge distributed from 101'-0" left to 150' left.
	Negative	(a) 2 hind wheels at 30'-0" left wt. 9·80 tons. (b) 1 fore wheel at 40'-67' left wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 47·83' left to 101'-0" left and 22·84' left to 6·4' right. (d)

Position of loading on roadway to give maximum moments in different sections of arch rib taken from B.M. influence line diagrams for arch rib (contd.)

Section at which moment is to be considered	Sign of B.M.	Details of loading
3 (45′-0″)	Positive	(a) 2 hind wheels at 45′-0″ right wt. 9·80 tons. (b) 1 fore wheel at 55·67′ right wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 62·83 ft. right to 6·50′ right. (d) ·337 tons ft. run of bridge distributed from 37·84 ft. right to 6·5′ left.
	Negative	(a) 2 hind wheels at 45′-0″ left wt. 9·80 tons. (b) 1 fore wheel at 55·67′ left wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 62·83′ left to 150′ left. (d) ·337 tons ft. run of bridge distributed from 37·84 ft. left to 6·5′ left.
4 (60′-0″)	Positive	(a) 2 hind rollers at 45′-0″ right wt. 9·80 tons. (b) 1 fore roller at 34·33 ft. right wt 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 52·16′ right 150′ right and 27·17′ right to 20′ left. (d)
		(a) 2 hind rollers at 60′ left wt. 9·80 tons. (b) 1 fore roller at 70·67′ left wt. 4·9 tons. (c) ·337 tons ft. run of bridge distributed from 77·83 ft. to 150′-0″ left (d) ·337 tons ft. run of bridge distributed from 52·84 ft. left to 20′-0″ left.
5 (75′-0″)	Positive	(a) 2 hind rollers at 30′-0″ right wt. 9·80 tons. (b) 1 fore roller 40·67′ right wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 47·83′ right to 150′ right. (d) ·337 tons ft. run of bridge distributed from 22·84′ right to 30′ left.
	Negative	(a) 2 hind rollers at 75′-0″ left wt. 9 80 tons. (b) 1 fore roller at 85·67′ left wt. 4·90 tons (c) ·337 tons ft. run of bridge distributed from 92·83′ left to 150′-0″ left. (d) ·337 tons ft. run of bridge distributed from 67·84 ft. left to 30′-0″ left.

Position of loading on roadway to give maximum moments in different sections of arch taken from B.M. influence line diagrams for arch rib (contd.)

Section at which moment is to be considered	Sign of B.M.	Details of loading
6 (90'-0")	Positive	(a) 2 hind rollers at 15'-0" right wt. 9·80 tons. (b) 1 fore roller at 25·67' right wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 32·83 ft. right to 150'-00" right. (d) ·337 tons ft. run of bridge distributed from 7·84 ft. to right to 48'-0" left.
	Negative	(a) 2 hind rollers at 90'-0" left wt. 9·80 tons. (b) 1 fore roller 100·67' left wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 107·83' left to 150'-0 left. (d) ·337 tons ft. run of bridge distributed from 82·84 ft. left to 48·00' left.
7 (105'-0")	Positive	(a) 2 hind wheels at 15'-0" left wt. 9·80 tons. (b) 1 fore wheel at 25·67' left wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 32·83' to 69'-0" (d) ·337 tons ft. run of bridge distributed from 7·84' left to 97'-0" right.
	Negative	(a) 2 hind wheels at 105'-0" left wt. 9·80 tons (b) 1 fore wheel at 94·33' left wt. 4·90 tons (c) ·337 tons ft. run of bridge distributed from 112·16' left to 150'-0" left and 87·17' to 69'-0" left. (d) ·337 tons ft. run of bridge distributed from 97'-0" right to 150'-0" right.
8(120'-0")	Positive	(a) 2 hind wheels at 60'-0" left wt. 9·80 tons. (b) 1 fore wheel at 94·33 ft. left wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 67·16' left to 102'-0" left. (d) ·337 tons ft. run of bridge distributed from 42·17 ft. left to 11'-0" right.
	Negative	(a) 2 hind wheels at 120'-0" left wt. 9·80 tons. (b) 1 fore wheel 130·67' left wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 137·83' left to 150'-0" left and 112·84' left to 120'-00" left. (d) ·337 tons ft. run of bridge distributed from 11'-0" right to 150'-0" right.

Position of loading on roadway to give maximum moments in different sections of arch taken from B.M. influence line diagram for arch rib (contd.)

Section at which moment is to be considered	Sign of B.M.	Details of loading
9 (135′-0″)	Positive	(a) 2 hind wheels at 90′-0″ left wt. 9·80 tons. (b) 1 fore wheel at 79·33′ left wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 97·16 ft. left to 130·5 ft. left and 72·17 ft. to 16 ft. left. (d) " "
	Negative	(a) 2 hind wheels at 45′-0″ right wt. 9·80 tons. (b) 1 fore wheel at 55·67′ right wt 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 37·84 ft. right to 16′-0″ left and 62 83 ft. right to 150′-0 right. (d) ·337 tons ft. run of bridge distributed from 130·5′ ft. left to 150′-0″ left.
10 (Springing)	Positive	(a) 2 hind wheels at 150′-0″ left wt. 9·80 tons. (b) 1 fore wheel at 94·33 ft. left wt. 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 112·16 ft. left to 150′-0″ left. (d) ·337 tons ft. run of bridge distributed from 87·17 ft. left to 29 5 ft left.
	Negative	(a) 2 hind wheels at 45′-0″ right wt. 9 80 tons. (b) 1 fore wheel at 55 67′ right wt 4·90 tons. (c) ·337 tons ft. run of bridge distributed from 37·84 ft. right to 29·5 ft left. (d) ·337 tons ft. run of bridge distributed from 62 83 ft. right to 150′-0″ right

Position of loading on roadway to give maximum shear in different sections of arch taken from influence line diagram for shear in arch rib.

Section at which moment is to be considered.	Sign of B.M.	Details of loading.
Crown	Positive	(a) 2 hind wheels at crown total weight 9·80 tons. (b) 1 fore wheel at 10·67 right weight 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 17·83 '. right to 150'-0" right. (d)
	Negative	(a) 2 hind wheels at crown total wt. 9·80 tons. (b) 1 fore wheel at 10·67' left wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 17·83'. left to 150'-0" left. (d)
1 (15'-0")	Positive	(a) 2 hind wheels at 15'-0" left wt. 9·80 tons. (b) 1 fore wheel at 4·33' left wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 2·83' right to 150'-0" right. (d)
	Negative	(a) 2 hind wheels at 15'-0" left wt. 9·80 tons. (b) 1 fore wheel at 25·67' left wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 32·8' left to 150'-0" left. (d)
2 (30'-0")	Positive	(a) 2 hind wheels at 30'-0" left of crown wt. 9·80 tons. (b) 1 fore wheel at 19·33 left of crown wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 12·17 '. left to 150'-0" right. (d)
	Negative	(a) 2 hind wheels at 30'-0" left of crown wt. 9·80 tons. (b) 1 fore wheel at 40·67' left of crown wt. 4·90 tons. (c) ·337 tons per ft run of bridge distributed from 47·85 '. left to 150'-0" left. (d)

Position of loading on roadway to give maximum shear in different sections of arch taken from influence line diagram for shear in arch rib. (contd.)

Section at which moment is to be considered.	Sign of B.M.	Details of loading.
3 (54'-0")	Positive	(a) 2 hind wheels at 45'-0" left of crown wt. 9·80 tons. (b) 1 fore wheel at 34·33' left of crown wt. 4·90 tons (c) ·337 tons per ft. run of bridge distributed from 27·17' to 61'-0" right. (d)
	Negative	(a) 2 hind wheels at 45'-0" left of crown wt. 9·80 tons. (b) 1 fore wheel at 55·57' left of crown wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 52·83 left to 150'-0" left. (d) ·337 tons per ft. run of bridge distributed from 61'-0" right to 150-0" right.
4 (60'-0")	Positive	(a) 2 hind wheels at 60'-0" left wt. 9·80 tons. (b) 1 fore wheel at 49·33' left wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 42·17' left to 23'-0" right. (d)
	Negative	(a) 2 hind wheels at 60'-0" left wt. 9·80 tons. (b) 1 fore wheel at 70·67' left wt. 4·9 tons. (c) ·337 tons per ft. run of bridge distributed from 77·83' left to 150'-0" left (d) ·337 tons per ft. run of bridge distributed from 23'-0" right to 150'-0" right.
5 (75'-0")	Positive	(a) 2 hind wheels at 75'-0" left wt. 9·80 tons. (b) 1 fore wheel at 64·33' left wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 57·17'-0" left to 3'-0" right. (d)
	Negative	(a) 2 hind wheels at 75'-0" left wt. 9·80 tons. (b) 1 fore wheel at 85·67' left wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 92·83'-0" left to 150'-0" left. (d) ·337 tons per ft. run of bridge distributed from 3'-0" right to 150'-0" right.

Position of loading on roadway to give maximum shear in different sections of arch taken from influence line diagram for shear in arch rib. (contd.)

Section at which moment is to be considered.	Sign of B.M.	Details of loading.
6 (90'-0")	Positive	(a) 2 hind wheels at 90'-0" left of crown wt. 9·80 tons. (b) 1 fore wheel at 79·33' left of crown wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 72·17' left to 14'-0" left. (d)
	Negative	(a) 2 hind wheels at 90'-0" left of crown wt. 9·80 tons. (b) 1 fore wheel at 100·67' left of crown wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 107·83' left to 150'-0" left. (d) ·337 tons per ft. run of bridge distributed from 14'-0" left to 150'-0" right.
7 (105'-0")	Positive	(a) 2 hind wheels at 105'-0" left wt. 9·80 tons. (b) 1 fore wheel at 94·33' left wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 87·17' left to 27'-0" left. (d)
	Negative	(a) 2 hind wheels at 45'-00" right wt. 9·80 tons. (b) 1 fore wheel at 34·33' right wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 27·17' right to 27'-00" left and 52·16' right to 150'-0" right. (d) ·337 tons per ft. run of bridge distributed from 105'-0" left to 150'-0" left.
9 (135'-0")	Positive	(a) 2 hind wheels at 90'-0" left wt. 9·80 tons. (b) 1 fore wheel at 79·33' left wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 97·16 ft. left to 130·5' ft. left and 72·17 ft. left to 16 ft left. (d) ·337 tons per ft. run of bridge distributed from 97·16 ft. left to 130·5' ft. left and 72·17 ft. left to 16 ft. left.
	Negative	(a) 2 hind wheels at 45'-0" right wt. 9·80 tons. (b) 1 fore wheel at 55·67 ft. right wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 37·84 ft. right to 16'-0" left and 62·83 ft. right to 150'-0" right. (d) ·337 tons per ft. run of bridge distributed from 130·5' left to 150'-0" left.

Position of loading on roadway to give maximum shear in different sections of arch taken from B.M. influence line diagram for shear in arch rib. (contd.)

Section at which moment is to be considered.	Sign of B.M.	Details of loading.
10 (Springing)	Positive	(a) 2 hind wheels at 105′-0″ left wt. 9·80 tons. (b) 1 fore wheel at 94·33 ft. left wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 112·16′. left to 150′-0″ left. (d) ·337 tons per ft. run of bridge distributed from 87·17″ left to 29·5′ left.
	Negative	(a) 2 hind wheels at 45′-0″ right wt. 9·80 tons. (b) 1 fore wheel at 55·67′ right wt. 4·90 tons. (c) ·337 tons per ft. run of bridge distributed from 37·84′. right to 29·5′. left. (d) ·337 tons per ft. run of bridge distributed from 62·83′ to 150′-0″ right.

Table XIII

DETERMINATION OF STRESSES AT VARIOUS SECTIONS.

(Maximum Negative Moment and Corresponding Thrust.)

Section.	Area in terms of concrete unit (sq.ft.)	Section Modulus (ft^3)	Stress due to dead load + live load				Stress due to temp. change + 40° F.					Maximum Stresses.	
			Bending Stresses.		Direct Stresses.			Bending Stresses.		Direct Stress			
			B.M. (ft. tons).	Stress (tn/sft.)	Thrust (tons)	Stress (tons/sft.)		B. M (ft.tons).	Stress (ton/ sq. ft.)	Thrust tons.	Stress. tons/ sq. ft.	Tons/ sq.ft.	lbs/ sq. in
0	12.29	20.30	314.76	±15.49	518.30	42 20	Moments due to rise in temperature of 40 F. Moments due to drop in temperature of 40 F.	104.60	±5.16	−6.52	−.531	+62.32 +21.02	+970 +327
1	12.365	20.64	368.11	±17.82	522.17	42.30		100.10	±4.87	−6.52	−.527	+64.46 +19.08	1+003 +297
2	12.440	20.83	408.00	±19.60	524.46	42.81		92.60	±4.44	−6.52	−.524	+66.33 +18.25	+1033 +284
3	12.515	21.01	484.30	±23.01	529.05	42.20		74.70	±3.55	−6.52	−.520	+68.24 +15.12	+1062 +235
4	12.590	21.01	512.13	±24.35	530.37	42.15		49.90	±2.37	−6.52	−.517	+68.35 +14.91	+1064 +232
5	12.665	21.10	374.19	±17.75	530.19	42.00		18.41	±.87	−6.52	−.515	+50.10 +22.86	+925 +356
6	12.740	21.57	192.30	±8.92	539.69	42.30		18.23	±.84	+6.52	+.511	+52.57 +33.05	+818 +514
7	12.815	21.98	190.01	±8.66	553.64	43.11		61.78	±.82	+6.52	+.507	+55.10 +32.14	+857 +500
8	12.890	22.41	160.29	±7.13	588.99	45.61		110.01	±4.92	+6.52	+.505	+58.17 +34.07	+905 +530
9	12.965	26.70	139.78	±5 22	622.43	48.11		169.21	±6.33	+6.52	+.502	+60.16 +37.06	+936 +577
10	13.040	32.89	394.33	±11.98	636.02	48.98		221.60	±6.72	+6.52	+.500	+68.18 +30.78	+1060 +478

Note.—Upper values denote stresses at the extrados.

Table XIV

DETERMINATION OF STRESSES AT VARIOUS SECTIONS.
(Maximum Positive Moment and Corresponding Thrust.)

SECTION	Area in terms of concrete unit (sq. ft.)	Section Modulus (ft³)	Stress due to dead load and live load. Bending Stresses. B.M. (ft. tons/sq. ft.)	Bending Stresses. Stress tons/sq. ft.	Direct Stresses. Thrust (tons)	Direct Stresses. Stress (tons/sq. ft.)		Stress due to Temperature change ±40°F. Bending Stresses. B.M. (ft. / tons)	Bending Stresses. Stress (tons/sq. ft.)		Direct Stresses. Thrust Tons	Direct Stresses. Stress tons/sq. ft.	Maximum Stresses. Tons/sq. ft.	Maximum Stresses. lbs./sq. in.
0	12·29	20·30	130·28	± 6·42	514·41	41·89	Moment due to rise in temperature of 40°F.	104·60	±5·15	Positive thrust.	+6·52	+·530	+53·99 +30·85	+840 +480
1	12·365	20·64	167·70	± 8·13	518·26	41·95		100·10	±4·93		+6·52	+·527	+55·54 +29·42	+863 +458
2	12·440	20·83	272·80	±13·09	523·12	42·05		92·60	±4·44		+6·52	+·524	+60·10 +25·04	+935 +390
3	12·515	21·01	340·71	±16·20	534·89	42·75		74·70	±3·55		+6·52	+·521	+63·02 +23·52	+980 +366
4	12·590	21·01	408·17	±19·41	549·39	43·65		49·90	±2·49		+6·52	+·518	+66·07 +22·27	+1027 +346
5	12·665	21·10	468·32	±22·22	558·86	44·30		18·41	± ·87		+6·52	+·514	+67·90 +21·72	+1056 +338
6	12·740	21·57	474·23	±22·00	584·31	45·90	Moment due to drop in temperature of 40°F.	18·23	± ·85	Negative thrust	−6·52	−·512	+68·24 +22·54	+1062 +350
7	12·815	21·98	366·03	±16·68	605·49	47·21		61·78	±4·82		−6·52	−·509	+68·20 +25·20	+1061 +392
8	12·890	22·41	348·76	±15·49	603·27	46·80		110·01	±4·92		−6·52	−·506	+66·70 +25·88	+1037 +403
9	12·965	26·70	553·23	±20·71	620·86	47·90		169·21	±6·33		−6·52	−·503	+74·44 +20·36	+1157 +317
10	13·040	32·89	869·73	±26·42	622·73	47·85		221·60	±9·74		−6·52	−·500	+80·51 +14·10	+1253 +221

Note.—Upper values denote stresses at the intrados.

Table XV

Maximum Stresses in different sections.

Sections.	Stress (Max.) in Pounds per sq. in.
Crown.	+ 970
1 (15′-0″)	+1003
2 (30′-0″)	+1033
3 (45′-0″)	+1062
4 (60′-0″)	+1064
5 (75′-0″)	+1056
6 (90′-0″)	+1062
7 (105′-0″)	+1061
8 (120′-0″)	+1037
9 (135′-0″)	+1157
10 (150′-0″)	+1253

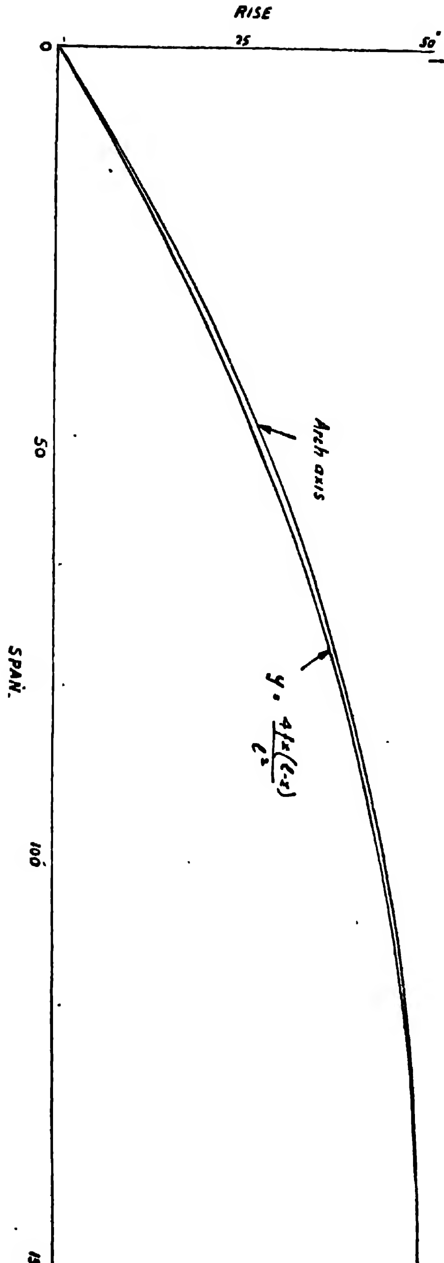

RISE
0
25
50'
50
100'
150
SPAN.
Arch axis
$y = \frac{4fx(l-x)}{l^2}$

Fig. A

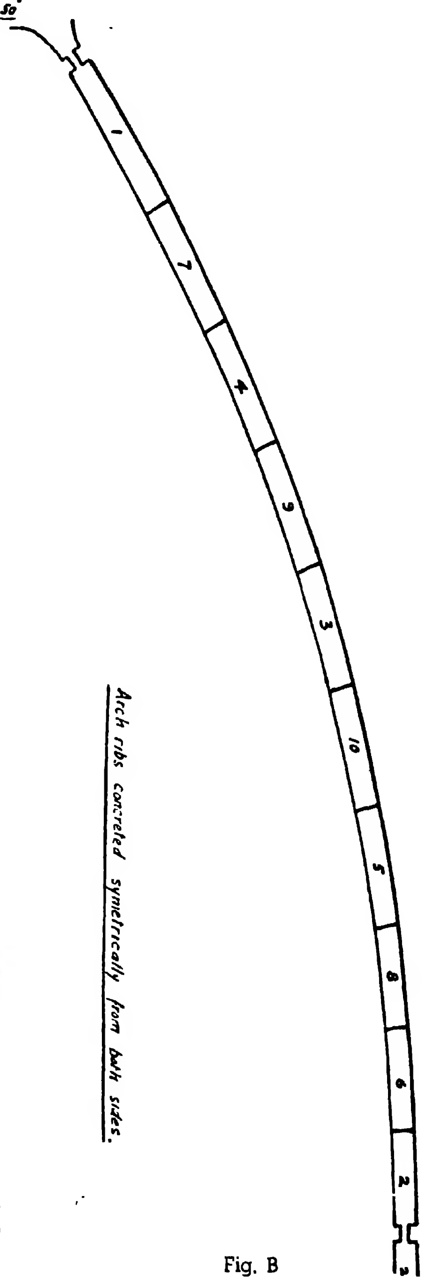

1
7
4
9
3
10
5
8
6
2
Arch ribs concreted symmetrically from both sides.

Fig. B

Arch Rib. Determination of Shape.—The first assumption was that the arch axis should be a parabola of the second degree, *i.e.*,

$$y = \frac{4fx(l-x)}{l^2}$$

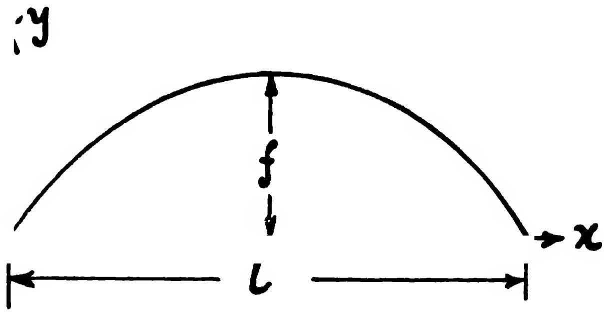


Fig. 38 where l = span of arch and f = rise of arch.

The position of the temporary hinges having been settled the arch was treated as three hinged having a clear span of 290 feet and a rise of 46·72 feet. Since a three hinged arch is statically determinate the moment at any point is easily calculated; the moment at any point divided by the normal thrust at the same point gives the eccentricity. The eccentricity for several points was calculated and the revised arch axis made to pass through these points, Fig. A page 313, shows the first approximation and the final shape. Assuming that the line of pressure follows the arch axis we know that the moments in the arch due to dead load are zero ; this statement holds as long as the temporary hinges are effective but once they are closed this relation is no longer necessarily correct. All calculations should now be made treating the arch as rigidly fixed, this has been done and tables XIII, XIV and XV give the maximum moments, normal thrust due to dead load, live load and temperature.

In calculating labour and material costs the following rates were allowed :—

Baider (mate)	... 1/-	per day	
Carpenter	... 1/4/-	,,	
Fitter	... 1/6/-	,,	
Mason	... 1/-	,,	
Men	... -/10/-	,,	Labour.
Women	... -/6/-	,,	
Boys	... -/4/-	,,	
Chinese Carpenter	... 2/8/-	,,	
Blacksmith	... 1/6/-	,,	
Cement	... 58/-	per ton.	
Sand	... 15/-	per % cu. ft.	
Machine Crushed Aggregate	... 35/-	per % cu. ft.	
Reinforcement	... 12/-	per Cwt.	
Wire	... -/4/-	per pound	Materials
Bamboos	... 5/-	per 100	
Nails	... 10/	per Maund.	
String	... 20/-	per Maund.	
Timber	... 1/-	per cu. ft.	
Cost of Running Mixer	... 2/-	per % cu. ft.	

The total cost of construction of the bridge was Rs. 3,69,339/-. It was opened by H. E. Sir John Anderson, P.C., G.C.B., G.C.I.E., on 26th October, 1933.

The bridge withstood the 1934 earthquake without damage and maintenance charges to date are nil.

The bridge was designed by the Author in consultation with Dr. M. A. Korni, M.I.E., who acted as Resident Engineer for the contractors, Messrs. Bird & Co., Calcutta.

ELECTRIC WAVE FILTER THEORY AND ITS APPLICATIONS

BY

S. N. MUKERJI,[1] *M.Sc., Associate Member; Assoc. M.I.R.E.*

Synopsis.

The paper attempts to indicate briefly the development of the theory of electric wave filters, which are playing such an important role in the development of modern Electrical Communication Engineering. The problem of wave transmission along a string loaded with weights at equal intervals had been treated by a large number of investigators such as Lagrange, Routh, Rayleigh Stokes, Godfrey, Vincent and Lamb but the "filtering" properties inherent in such structures were not brought out clearly. A discussion of the classical theory of the loaded string is given in order to emphasise this "filtering" action. Crandall's treatment of the problem, presented at some length here, helps to bring out the "low-pass" filtering properties of a loaded string when steadily driven by a harmonic force. The problem of loading telephone transmission lines to get improved transmission characteristics is next dealt with and this leads us to the masterly works of Pupin and Campbell. Campbell was led to his invention of the electric wave filter from this study of loaded transmission lines. The basic theory and characteristics of the various types of wave-filters are next reviewed. The paper ends with a short account of a few of the important applications of electric wave filters such as ripple filters, co-axial cable inter-valve filters and other uses in thermionic tube systems, use in carrier current communication systems, crystal wave filters and magnetostriction oscillators as filters.

Introduction.—The invention of the Electric Wave Filter marks an important landmark in the development of Electrical Communication Engineering. It also exemplifies the evolutionary character of organized industrial research. It is the outcome of researches conducted for purposes very remote from the needs which the apparatus now meets. The importance of Electric Wave Filters could be judged from the large amount of money invested in them in diverse applications but their actual value far exceeds any estimate in money value. But for the development of filters many of the savings made in recent developments of long-distance telephony could not have been realized and advances which are now being made would have been quite impossible.

1. Government Test House, Alipore, Calcutta.

Note. Written Comments are invited for publication.

In electrical communication apparatus and systems, needs often arise for eliminating currents of particular frequencies or for separating two or more currents of different frequencies. For this purpose, use is made of what are called "*selective networks*" which may be defined as "networks or circuits designed to give a predetermined ratio between input and output currents (or voltages) for each given frequency." When such a selective network has characteristics which at certain frequencies, change rapidly with the frequency, it is called a "*wave filter*". The usual form of wave filter passes currents of some frequencies with little or no diminution of their effective values and practically eliminates currents of all other frequencies.

The development of electric wave filters can be traced back to the year 1903 when Dr. G. A. Campbell, then of the American Telegraph and Telephone Company, as a result of his studies in the theory of loaded telephone transmission lines, discovered the filtering properties of such structures. The problem of loading transmission lines to bring about distortionless transmission is similar to the problem of a string loaded with weights at equal intervals. The latter is a classical problem in oscillation mechanics. Lagrange in his "Mechanique Analytique" first gave a general solution of the problem of the loaded string. Routh after a discussion of Lagrange's solution points out that there may be a period of excitation of the string which is, "so short that.........no motion of the nature of a wave is transmitted along the string." Rayleigh, in his classical treatise on Sound, has investigated the question of wave reflection at the transition point between two strings of equal tension but of different loading, and derives an equation for the ratio of reflected to incident amplitude, which is virtually the same as the equation for optical reflection. The analogy between the mechanical problem and that of optical dispersion has been dealt with by various writers since the time of Stokes. Godfrey has dealt with the propagation of waves along a loaded string and its optical analogy. Vincent describes a dispersion model (a periodically weighted string) which has a definite frequency limit of wave transmission. Lamb has discussed the problem of waves in a medium having a periodic discontinuity of structure. In a one-dimensional medium of this character, he has found that there are very definite selective properties, for waves of certain frequencies, and in conclusion, pointed out that "a dynamically equivalent problem is that of propagation of sound waves along a tube having a series of equidistant bulbuous expansions............"

The Problem of the Loaded String.—As the problem of a long tense string loaded with equal masses spaced equally forms the starting point in the development of electrical wave filters, it may be of interest to discuss it in some detail here.

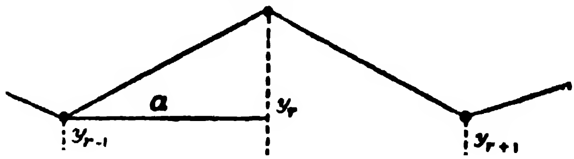


Fig. 1

Let us consider the motion of a string on which are fastened a number of beads of equal mass equidistant from each other and from the ends of the string, the mass of the string being neglected in comparison. Let the number of beads be n, the mass of each being m, the distances apart being a, and the length of the string $l=(n+l)a$. Suppose, for simplicity, that the motion of each bead takes place in a plane and transverse to the length of the stretched string, so that the displacement of the rth bead is y_r. Then the total kinetic energy of the beads in the displaced position at any time is given by

$$T=\tfrac{1}{2}m\left[\dot{y}_1^2+\dot{y}_2^2+ \quad \ldots \quad \ldots \quad +\dot{y}_n^2\right] \quad \ldots \quad (1)$$

The co-efficients of inertia are the same for all and equal to the mass for any bead. The displacements being very small quantities, the length of the string connecting any two beads is equal to "a" plus a small quantity of second order in comparison with "a", and hence the latter can be neglected. The tension of the string will thus be considered constant and equal to S. Neglecting the weight of the beads, the only forces acting on a bead are the components of the tensions of the two adjacent portions of the string in the direction of the displacement y. To find the component we have to multiply the tension by the cosine of the angle made by the displacement with the segment of the string, which is the difference of two consecutive displacements divided by "a". Accordingly, the force on the rth bead is

$$\frac{S}{a}\left[\left(y_{r+1}-y_r\right)-\left(y_r-y_{r-1}\right)\right]$$

$$=\frac{S}{a}\left[\left(y_{r-1}-y_r\right)+\left(y_{r+1}-y_r\right)\right] \quad . \quad (2)$$

$$= -\frac{\partial W}{\partial y_r}, \text{ where } W = \text{potential energy.} \qquad .. \qquad (3)$$

Integrating (3) we get

$$W = \frac{S}{2a}\left[y_1^2 + (y_2 - y_1)^2 + (y_3 - y_2)^2 + \ldots\ldots + y_n^{\,2}\right] \qquad .. \qquad (4)$$

We can now form the Lagrangian differential equations of motion as follows:

$$\left.\begin{array}{lcl} m\ddot{y}_1 + \frac{S}{a}(y_1 - 0 + y_1 - y_2) & = & 0, \\ m\ddot{y}_2 + \frac{S}{a}(y_2 - y_1 + y_2 - y_3) & = & 0, \\ .. \quad .. \quad .. \quad .. & & .. \\ m\ddot{y}_n + \frac{S}{a}(y_n - y_{n-1} + y_n - 0) & = & 0, \end{array}\right\} \qquad (5)$$

Let us take as the solution $y_r = A_r e^{\lambda t}$.

Substituting in (5) we get

$$\left.\begin{array}{l} m\lambda^2 + \left(\frac{2S}{a}\right)A_1 - \frac{S}{a}A_2 \qquad = 0, \\ -\frac{S}{a}A_1 + \left(m\lambda^2 + \frac{2S}{a}\right)A_2 - \frac{S}{a}A_3 = 0. \\ .. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \end{array}\right\} \qquad \ldots \quad (6)$$

Dividing through by S/a and putting $\left(\frac{ma\lambda^2}{S} + 2\right) = C$, we get

$$\left.\begin{array}{lcl} CA_1 - A_2 + 0 + \quad .. \quad .. & = & 0, \\ -A_1 + CA_2 - A_3 + 0 \quad .. \quad .. & = & 0, \\ 0 - A_2 + CA_3 - A_4 + 0 + \quad .. & = & 0. \\ \ldots \quad \ldots \quad \ldots \quad \ldots & & \end{array}\right\} \qquad \ldots \quad (7)$$

The determinantal equation for (7) then becomes

$$D_n = \left|\begin{array}{cccccc} C, & -1, & 0, & 0, & 0, & .. \\ -1, & C, & -1, & 0, & 0, & .. \\ 0, & -1, & C, & -1, & 0, & .. \\ \ldots & \ldots & \ldots & & \ldots & .. \end{array}\right| = 0 \qquad (n \text{ rows}) \qquad (8)$$

We can expand this determinant in terms of its first minors. Thus

$$D_n = C\,D_{n-1} - D_{n-2} \qquad \dots \quad (9)$$

or,

$$C\,D_{n-1} = D_n + D_{n-2}. \qquad \dots \quad (10)$$

This equation between three consecutive determinants of the same form suggests a trigonometrical relation:

$$2A \sin n\theta \cos \theta = A\left[\sin (n+1)\,\theta + \sin (n-1)\,\theta\right] \qquad \dots \quad (11)$$

provided the constant A is correctly determined, the transformation being from variable C to θ. If $C=2\cos\theta$, we must have

$$D_n = A \sin (n+1)\theta. \qquad \dots \quad (12)$$

To evaluate A, put $n=1$; then

$$D_1 = C = 2\cos\theta = A \sin (1+1)\,\theta = 2A \sin\theta \cos\theta$$

or,

$$A = 1/\sin\theta\ , \qquad \dots \quad (13)$$

and finally

$$D_n = \sin (n+1)\theta/\sin\theta\ .$$

For D_n to vanish,

$$(n+1)\theta = k\pi\ , \qquad (k=1, 2\ 3, \ \dots n)$$

or,

$$\theta = k\pi/(n+1).$$

$$\text{or, } C = 2 + ma\lambda^2/S = 2\cos\theta = 2\cos\frac{k\pi}{n+1} \qquad \dots \quad (14)$$

$$\text{or} \qquad 2 + ma\lambda^2/S = 2\left[1 - 2\sin^2\frac{k\pi}{2\,(n+1)}\right]$$

This gives

$$-\lambda^2 = \frac{4s}{ma}\sin^2\frac{k\pi}{2\,(n+1)}. \qquad \dots \quad (15)$$

Putting $\lambda = iv$ we get

$$v = 2\sqrt{\frac{S}{ma}}\cdot\sin\frac{k\pi}{2\,(n+1)}. \qquad \dots \quad (16)$$

Letting $k=1,2,\dots\dots\dots n$, we obtain n different frequencies proportional to the ordinates of points dividing a quadrant into $(n+1)$ equal parts. If the number of particles or sections of the string is very large, we can write for the highest natural frequency f_m

$$f_m = f_o = \frac{1}{\pi}\sqrt{\frac{S}{ma}}. \qquad \dots \quad (17)$$

No frequency greater than this can be propagated along the loaded string. This, therefore, gives what can be called the "cut-off" frequency of the loaded string. The filtering action of a structure like the loaded string is thus brought out. Crandall has further investigated the filtering properties of such structures when steadily driven by a force of frequency $\omega/2\pi$.

Let a force $\Psi_1 = \Psi_0 e^{i\omega t}$ be applied to the particle 1. Then we have for the displacements of the particles nearest the beginning and end of the string, according to the theory of vibrations,

$$y_1 = \frac{M_1}{D_n} \Psi_1 \text{ and } y_n = \frac{M_n}{D_n} \Psi_1, \qquad \dots \quad (18)$$

where M_k is the minor of D_n obtained by suppressing the jth row and kth column, D_n being the determinant as already given.

Now $M_1 = D_{n-1}$ and $M_n = 1$;

$$\therefore \frac{y_n}{y_1} = \frac{1}{D_{n-1}} . \qquad \dots \quad (19)$$

If n is large, D_{n-1} has a succession of $(n-1)$ roots within the same region of frequency as those of D_n *i.e.*, within the region of natural oscillations, and that in this frequency range y_n/y_1 has appreciably larger values, that is to say that oscillations produced at one end of the structure travel easily to the other end. The thing which is most interesting from our point of view is the value of y_n/y_1 when the driving force has a frequency slightly in excess of the highest natural frequency of the system. So we have to determine the value of D_{n-1} for $w > 2\pi f_o$.

$$\text{Now } C = 2 + \frac{ma\lambda^2}{S}, \text{ and } \lambda^2 = -w^2.$$

Putting $S/ma = v_o^2/4$ we have

$$C = 2\cos\theta = 2 - \frac{4w^2}{v_o^2},$$

$$\text{or, } \cos\theta = 1 - 2\frac{w^2}{v_o^2} . \qquad \dots \quad (20)$$

If $w > v_o$, θ becomes imaginary.

Let $\theta = \pi + i\theta$,

Then $-\cosh\theta = \cos(\pi + i\theta)$,

$$\text{and } D_{n-1} = \frac{\sin n(\pi + i\theta)}{\sin(\pi + i\theta)} = (-)^{n-1} \frac{\sinh n\theta}{\sinh\theta} \qquad \dots \quad (21)$$

$$\text{and } \tfrac{1}{2} C = 1 - 2\frac{w^2}{v_o^2} = -\cosh\theta. \qquad \dots \quad (21)$$

The general course of D_{n-1} (C) as a function of w/v_o is indicated in Fig 2, for $n=10$. The roots of D_{10} (C) (10 natural frequencies of the string) are also indicated by vertical lines. A study of this particular case, based on the behaviour of D_{10} (C) and D_9 (C) shows clearly the filtering action of a string equally loaded only at 10 points. At the point P, which represents D_9 for a value of $w/v_o = 1{\cdot}05$ computed by equation (21) the relatively small value of $y_{10}/y_9=2/D_9$ is strikingly shown as compared with the values of $1/D_9$ in the resonant range. As w/v_o is further increased, D_9 still rises rapidly and it is evident that the string acts as a very efficient low-pass filter, cutting off all vibrations of frequency greater than $v_o/2\pi$.

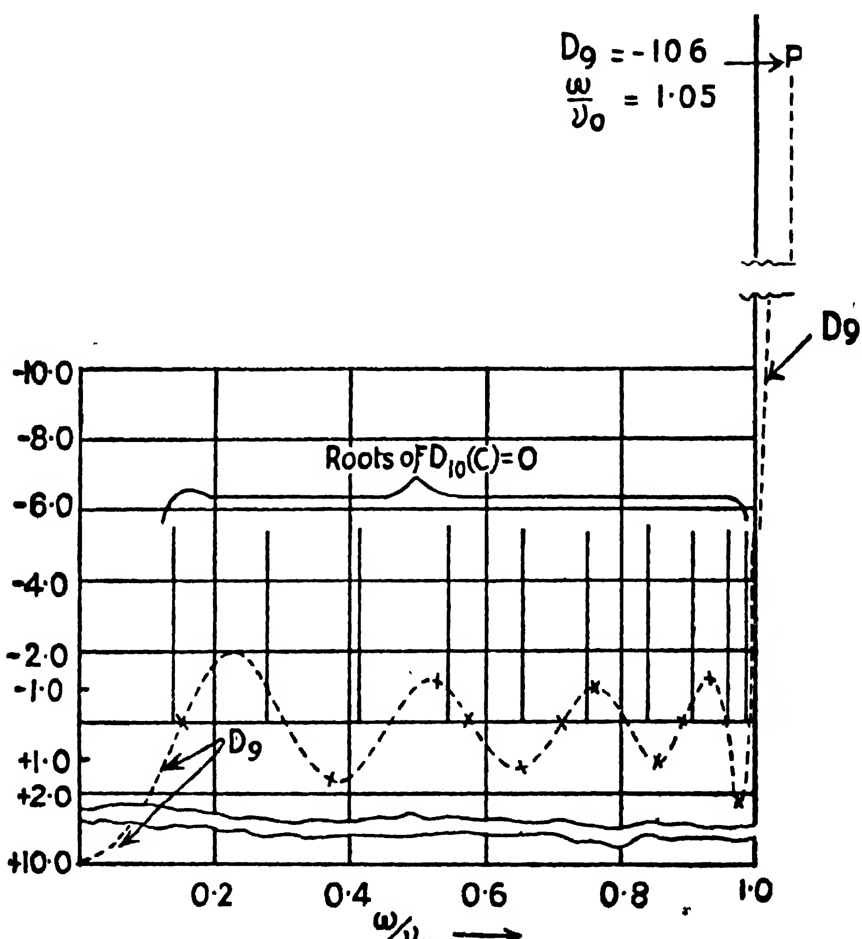


Fig. 2.—Properties of D_{10} (C) and D_9 (C)—Loaded String.

The Problem of the Loaded Transmission Line and the Evolution of the Electric Wave-Filter. It is well-known in telephone transmission theory that if the distributed primary circuit parameters (L,G,C and R) are so related that LG=CR (Heaviside's Law), the circuit will be theoretically distortionless. In such a circuit, the attenuation, wave velocity and line characteristic impedance will be independent of frequency, as also the attenuation will be minimum. For the usual transmission circuits, the product CR is greater than LG. The most practicable way of approaching the relation LG=CR is to "load" the circuit inductively. This is done by adding coils in series in the line wires at uniformly spaced points (coil or lumped loading). This method of increasing the efficiency of telephone transmission circuits was first suggested by Oliver Heaviside in 1887, who, however, did not point out any practical way of introducing the inductance. It was in 1899 and 1900 that Prof. Michael Pupin of America published two masterly papers in which he investigated the properties of loaded cables. He extended the method outlined in the previous section for the case of a *light* loaded string to the problem of vibrations of a *heavy* string loaded with beads and applied the analysis to find out the time of electrical vibrations of the analogous case of a coil-loaded telephone cable. At about the same time, Campbell working independently along somewhat different lines also developed a theory of loaded cables. Priority in the discovery was adjudged Pupin and his patent rights were acquired by the Bell System whose engineers have been largely responsible for the application of loading to modern communication circuits. Fleming has given a shorter method of deriving Pupin's equation for the velocity of propagation of an electric wave along a coil-loaded telephone cable which we propose to discuss here in order to bring out the filtering properties inherent in such cases.

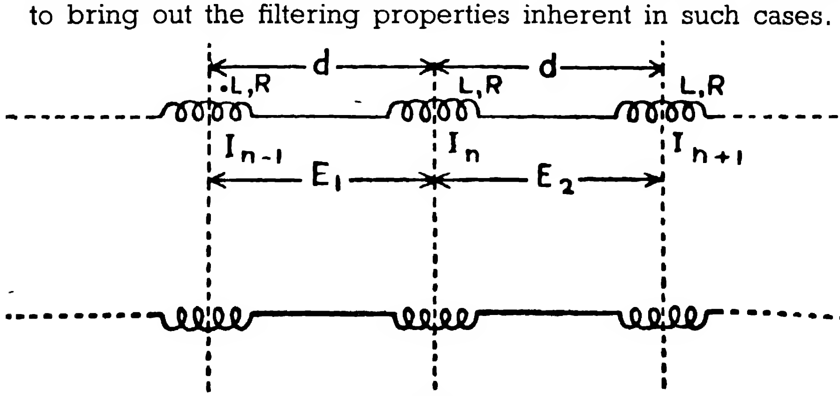


Fig. 3.—Coil-loaded telephone Cable.

Let us suppose that loading coils each having an inductance L_1 and resistance R_1 are inserted at intervals d along a two-wire cable having the usual distributed circuit parameters R,L,G and C. Let I_{n-1}, I_n and I_{n+1} be the currents through three successive loading coils and let E_1 be the P.D. at a point half-way between $(n-1)th$ and nth coils and E_2, the corresponding P.D. between the nth and $(n+1)th$ coils. Let the currents and potentials be S.H. functions of time and vary as the real part of e^{jwt} where $j = \sqrt{-1}$ and $w = 2\pi \times$ frequency.

Hence $\frac{d}{dt} = j\omega$ and $\frac{d^2}{dt^2} = -\omega^2$.

Let us consider the section of the cable between the $(n-1)th$ and the nth loading coils. The average gradient of the current in that section of the cable is $(I_{n-1} - I_n)/d$ and if this gradient line is nearly straight, the gradients must be equal to $(G+jwC)\ E_1$. Similarly $(I_n - I_{n+1})/d = (G + jwC)\ E_2$.

Taking the difference $\left\{ (I_{n-1}-I_n)-(I_n - I_{n+1}) \right\}/d$

$= (G + jwC)\ (E_1-E_2)$.

But $E_1-E_2=I_n\ (R+jwL)\ d$, if by R and L we denote the average resistance and inductance of the loaded cable per unit length.

Hence $I_{n-1}-2I_n + I_{n+1}=I_n (G+jwC)\ (R+jwL)d^2$ .. (22)

Let $I_n = I_o \sin(wt-kx)$, where $w=2\pi/T$, T being periodic time, $k=2\pi/\lambda$, λ being wave length, and $x=nd$.
Substituting in Equation. (22)

$$\cos\left\{ wt-(x-d)\ k\right\} - 2\cos(wt-kx)+\cos\left\{ wt - k(x+d) \right\}$$

$$=\cos(wt - kx)\left[GR - w^2 LC + jw\,(CR + LG)\right] d^2.$$

$$\text{or } (jw)^2 + 2\left(\frac{R}{2L} + \frac{G}{2C}\right) j\omega = -\left(\frac{4}{LCd^2}\sin^2\frac{kd}{2} + \frac{RL}{GC}\right)$$

$$\left\{\because (jw)^2 = -w^2\right\} \qquad (23)$$

Solving this quadratic we derive

$$jw = -\left(\frac{R}{2L}+\frac{G}{2C}\right) \pm j\sqrt{\frac{4}{LCd^2}\sin^2\frac{\pi d}{\lambda} - \left(\frac{R}{2L} - \frac{G}{2C}\right)^2} \qquad (24)$$

$$\text{or}\quad f = \frac{w}{2\pi} = \frac{1}{\pi d}\sqrt{\frac{1}{CL}\sin^2\frac{\pi d}{\lambda} - \left(\frac{Rd}{4L} - \frac{Gd}{4C}\right)^2}. \qquad (25)$$

If $R/L = G/C$, then $f = \frac{1}{\pi d}\sqrt{\frac{1}{CL}\sin^2\frac{\pi d}{\lambda}} = \frac{1}{\pi d\sqrt{LC}}\sin\frac{\pi d}{\lambda}$ ... (26)

or $f_{max} = \frac{\quad}{\pi d\sqrt{LC}}$. ... (27)

This is the cut-off frequency of the coil-loaded line. The line will not transmit any frequency greater than this value. The phenomenon may also be compared with the formation of absorption lines in the spectra in which a medium is transparent, or more or less opaque, in accordance with the wave-length of the incident light. Fig. 4 gives the attenuation characteristics of a loaded and unloaded line.

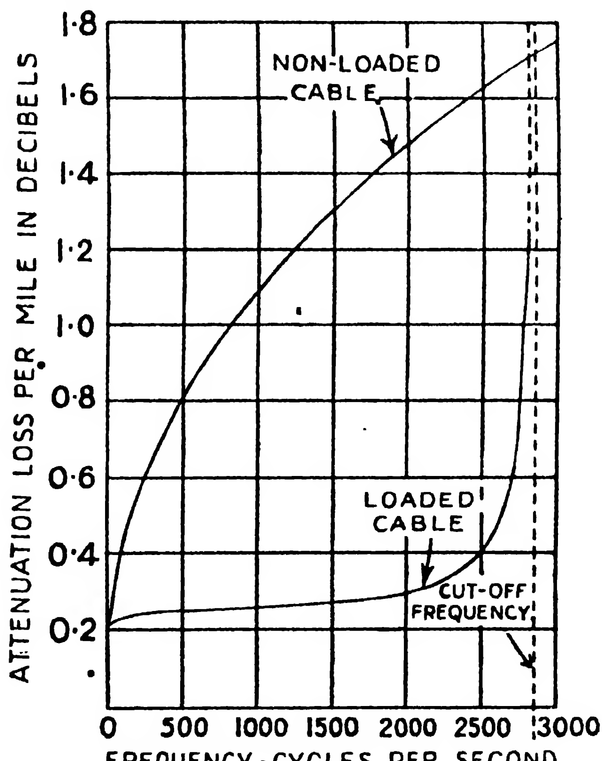


Fig. 4. Attenuation-Frequency Characteristics of Loaded and Unloaded Cable.

It will be seen that the transition from improved transmission at low frequencies to impaired transmission at high frequencies is very striking. The loaded line is now looked upon as a low-pass filter, the loading coils providing series

inductance and the line wires, shunt capacitance. Campbell was inspired by his discovery to study the general case of a reiterative ladder type net-work in which the reactances of rungs and side arms of the ladder were generalized. Thus was laid the foundation of the fascinating study of electric wave filters and their applications. Campbell's ideas were followed up principally by O.J. Zobel, Shea, Johnson, Cauer and Bode, to name a few amongst a large number of contributors to an extensive and rapidly growing subject. The classical treatment of Campbell has generally been followed in these investigations. Bode has recently tried to formulate the general theory of electric wave-filters by reconciling the wave method of analysing net-works with the normal co-ordinate method well-known in ordinary vibration machanics.

Theory of Electric Wave Filters.—With the definition of an electric wave filter given in the introduction, its theory can be most conveniently developed from the behaviour of a ladder-like net-work, the longitudinal members of which are each composed of a series impedance Z_1 while the transverse members are each formed by a shunt impedance Z_2.

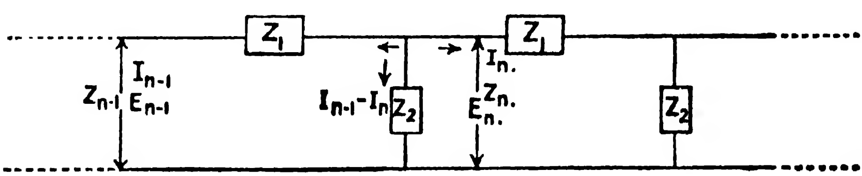


Fig. 5. Electric Wave-Filter of the Ladder Type.

Let us designate by E_{n-1} and I_{n-1}, the P.D. and the current respectively at the input terminals of the $(n—1)$ *th* section of the ladder and by E and I , the corresponding quantities at the output terminals of the same section or at the input terminals of the next, *viz.*, the *nth* section. Let $Z_{n-1} = Z_n$, then $E_{n-1} / I_{n-} =$ E_n / I_n. .. (27)

Applying Kirchoff's law we have

$$\left.\begin{aligned} E_{n-1} &= I_{n-1}Z_1 + E_n\,, \\ E_n &= (I_{n-1} - I_n)\, Z_2 \end{aligned}\right\} \quad \text{.. (28)}$$

From Eq. (27') we get

$$E_{n-1} / E_n = I_{n-1} / I_n = x, \text{ say.}$$

or

$$E_{n-1} = x\,E_n\,,$$

$$I_{n-1} = x\,I_n\,;$$

$$\therefore\quad E_n(x-1) = I_{n-1}Z_1$$

or

$$(I_{n-1} - I_n)\, Z_2\, (x-1) = I_{n-1}Z_1 \quad \text{.. (29)}$$

or, $(x-1) = \frac{I_{n-1}}{I_{n-1} - I_n} \frac{Z_1}{Z_2}$

$$= \frac{Z_1}{Z_2}\left\{ \frac{1}{1 - \frac{I_n}{I_{n-1}}} \right\} = \frac{Z_1}{Z_2}\left\{ \frac{1}{1 - \frac{1}{x}} \right\} = \frac{Z_1}{Z_2} \cdot \frac{x}{x-1} \qquad .. (30)$$

or $\frac{Z_1}{Z_2} = \frac{(x-1)^2}{x} = \frac{x^2 - 2x + 1}{x}$,

or $\frac{Z_1}{Z_2} x = x^2 - 2x + 1$,

or $x^2 - 2x\left(1 + \frac{Z_1}{2Z_2}\right) + 1 = 0. \qquad .. (31)$

Put $b = 1 + \frac{Z_1}{2Z_2} = \cosh P$.

Then $x^2 - 2\,xb + 1 = 0$

or, $x = \frac{2b \pm \sqrt{4b^2 - 4}}{2} = b \pm \sqrt{b^2 - 1}$ (+when $x > 1$, − when $x < 1$)

$$= \cosh P \pm \sinh P = \epsilon^{\pm P}. \qquad ... (32)$$

P is analogous to the propagation constant of an infinite transmission line. P is in general complex given by $P = \alpha + j\,\beta$, where α is called the attenuation constant and β the the phase constant. If $\alpha = 0$, the current will not be attenuated as it passes from section to section but will only be shifted in phase.

Thus $\cosh P = \cosh j\,\beta = \cos \beta$.

Limits of $\cos \beta$ are + 1 and − 1.

Therefore, $1 + \frac{Z_1}{2Z_2}$ lies between 1 and — 1.

or $Z_1 / 2Z_2$ lies between 0 and — 2.

or $Z_1 / 4Z_2$ lies between 0 and — 1.

Thus the condition for unattenuated transmission can be written as

$$-1 < Z_1 / 4Z_2 < 0, \quad \text{or} \quad -4 < Z_1 / Z_2 < 0 \qquad .. (33)$$

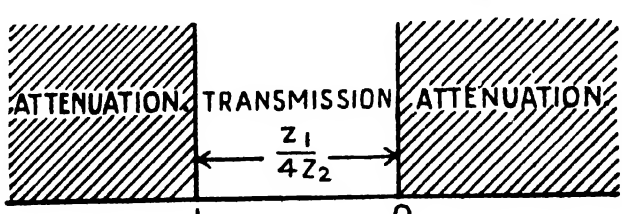


Fig. 6.—Illustrating Pass and Attenuated bands.

These results are shown schematically in Fig. 6. Thus there is but one range of values which $Z_1/4Z_2$ may have for transmission bands, *viz.*, that in which the ratio is negative and less than unity in magnitude ; but there are two ranges of values which $Z_1/4Z_2$ may have for attenuation bands *viz.*, those in which the ratio is positive or is negative and has a magnitude greater than unity.

The above is the basis of electric wave filter theory, for we have shown that it is possible for a structure to have the property of being non-attenuating for currents of one band of frequencies while attenuating currents in another band. A convenient practical way to locate the transmitting bands of ladder-filter sections is to sketch together as a function of frequency, Z_1 and $-4Z_2$ as shown in Fig. 7. The solid curves are Z_1 and the dotted curves are $-4Z_2$. The vertical lines locate frequencies of series or parallel resonance. Transmission then occurs for the frequency range where the two curves fall on the same side of the horizontal axis and Z_1 is less in absolute value than $4Z_2$. The location of the four separate transmission ranges is shown by the heavy portions of the horizontal axis.

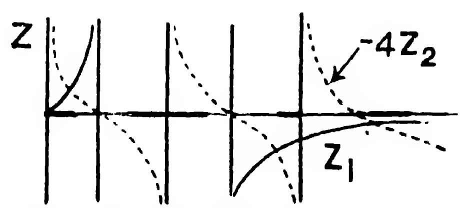


Fig. 7. Locating Transmission Bands of Ladder Filter Sections.

Types of Wave Filters.—Although wave filters may be designed having any number of transmitting and attenuating bands, the following types are the ones in most common use :—

(a) ***A low-pass Filter.***—Transmitting all frequencies from zero up to a certain desired frequency and attenuating all higher frequencies.

(b) ***A High-pass Filter.***—Attenuating all frequencies from zero up to a desired frequency and transmitting all other frequencies.

(c) ***A Band-pass Filter.***—Transmitting all frequencies between a lower and an upper desired frequency and attenuating all other frequencies.

· (d) ***A Band-elimination Filter.***—Attenuating all frequencies between two desired frequencies and transmitting all other frequencies.

In order to conform to the description given above, it is necessary that the circuit elements shall be pure reactances. Although in practice these are unobtainable, much of the essential filter theory is worked out on the assumption of no ohmic losses in the circuit. For most practical cases, however, the consequences of ignoring ohmic losses in design calculations are not very serious.

Characteristics of the Different Types of Filters.—We have seen before that the frequencies bounding the transmission band may be found by solving the equations

$$Z_1/Z_2 = 0, \quad Z_1/Z_2 = -4.$$

When Z_1 and Z_2 are each a single inductance or single capacitance, it follows that the solution of the first of these equations is $w=0$ or $w=\infty$, w being the frequency of the alternating current supplied to the line. The solution of the second equation yields a finite value for w, so that by the use of single inductance and single capacitance elements it appears possible to build low-pass and high-pass filters as already described. Such filter sections are illustrated in Figures (a) and (b).

For Fig. (a), we have $Z_1/Z_2 = w^2L_1C_1$, so that the transmission band lies between zero frequency and a cut-off frequency given by $w = {}^1/_2\sqrt{LC}$. For (b), $Z_1/Z_2 = 1/w^2L_2C_2$, so that the

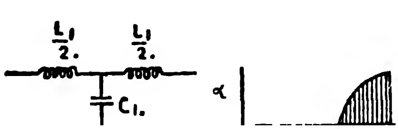


Fig. (a)—Low-pass.

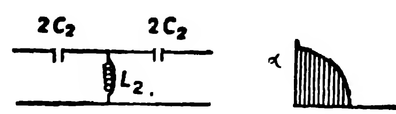


Fig. (b)—High-pass.

transmission band lies between infinite frequency and a cut-off frequency given by $w = {}^1/_2\sqrt{LC}$.

A Band-pass filter is formed by joining in series simple low-pass and high-pass filters of equal iterative impedance, the transmission band of which is bounded by the cut-off frequencies of the two simple filters. In this case

$$Z_1/Z_2 = C_4\,(1-w^2L_3C_3)\,/C_3 \qquad [\textit{vide}\ \text{Fig. (c)}]$$

the lower and the upper bounding frequencies being given by

$$w_l = 1/\sqrt{L_3C_3} \qquad \text{and } w_u = \sqrt{\frac{(4C_3 + C_4)}{C_3C_4L_3}}.$$

M-Derived Filters and Composite Filters.—The filters discussed belong to what is called the "Constant-K" group, in which Z_1 and Z_2 are inverse reactance arms, *i.e.*, $Z_1 Z_2 = K^2$.

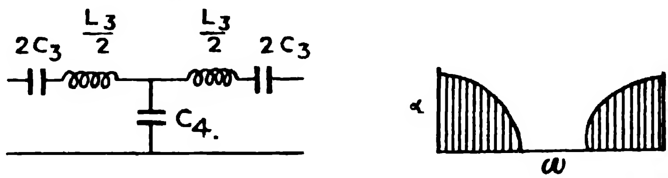


Fig. (c)—Band-pass.

In such "Constant-K" types of filters, the attenuation in the attenuating band is finite so that the complete rejection of the unwanted frequencies is not possible. If some filter could be found for which, even at one frequency, the attenuation were infinite, then it would be possible, by combining a number of such filters, arranged to have infinite attenuation at different frequencies, to obtain a filter rejecting a whole band of frequencies. Zobel first showed that it is possible simply to *derive* from symmetrical "Constant-K" net-works of the type already considered, more complex networks of the same impedance and cut-off frequency but of different propagation constant and exhibiting infinite impedance at one frequency. Figures (d), (e) and (f) show how these are derived from their prototypes. These are the so-called "M-derived filters."

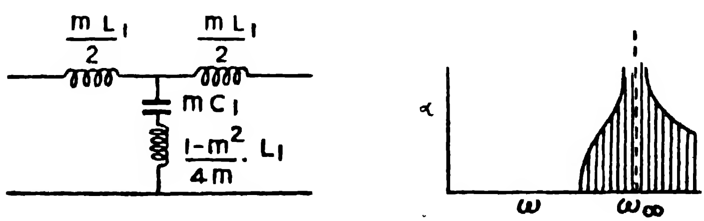


Fig. (d)—M-derived Low-pass.

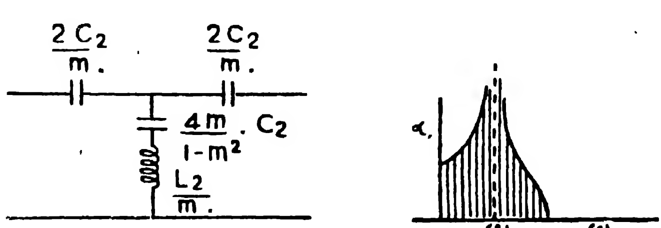


Fig. (e)—M-derived High pass.

The rigid requirements of some phases of modern communication have made desirable certain "composite" filters which may consist of one or more constant-K sections terminated with m-derived half-sections. Such composite filters can be made to have very high attenuation close to the cut-off point and to offer a quite uniform iterative impedance throughout most of the band of frequencies transmitted.

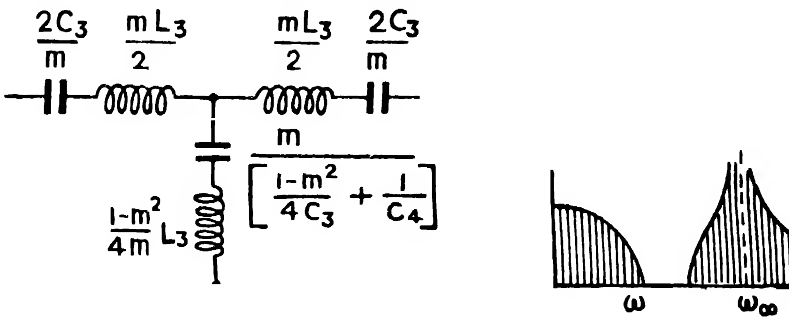


Fig. (f)—M-derived Band-pass.

Applications.—Electric Wave Filters find application in diverse fields, of which I propose to discuss a few of the most important ones.

1. ***Ripple Filters.***—The power supply for the modern radio-sets is practically always obtained by rectifying an A.C. supply. The output voltage of a rectifier consists of a direct-current component upon which is superposed A.C. voltage. For example, in the case of a full-wave single phase full-wave rectifier the output wave has the equation :

$$\frac{2E}{\pi}\left[1 - \quad \cos 2\omega t - \frac{2}{15}\cos 4\omega t - \frac{2}{35}\cos 6\omega t \ldots\ldots\ldots\right.$$

where E represents the crest-value of the A.C. voltage applied to the rectifier tube and w is the angular velocity 2π f of the supply frequency. In this case the D.C. component of the output wave is $2/\pi$ times the crest-value of the A.C. wave, the lowest frequency A.C. component in the output is twice the supply frequency and has a magnitude that is two-thirds of the D.C. component, and the remaining A.C. components are harmonic of the lowest frequency component. These pulsations must be smoothed out before the power is put into the plate circuits of the radio tubes, as these would cause audiomodulation of the output of the receiver. Filters are used for this purpose and are generally low-pass filters designed to pass

currents of all frequencies below a critical frequency and to reduce substantially the amplitude of currents of all frequencies above the critical frequency. This is shown graphically in Fig. 8.

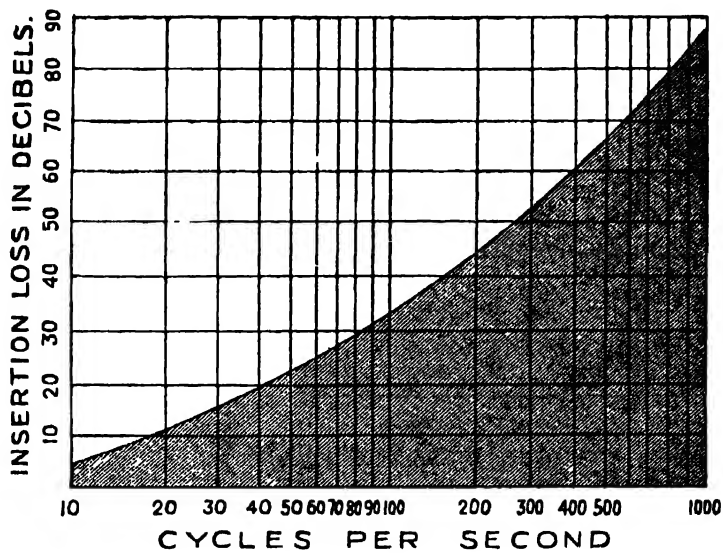


Fig. 8.—Ripple Filter Performance Curve.

(All frequencies passed in shaded portion.)

The curve shows that when the particular low-pass filter represented by this graph is inserted in the line, the insertion loss at 20 cycles is 10 d.b., at 50 cycles about 20 d.b., at 60 cycles 24 d.b., at 120 cycles 35 d.b. and so on. Hence it is seen that any low-frequency hump which gets through the filter is of a very low power value, the exact level depending of course upon the initial value of the ripple frequency.

2. ***Use of Filters in Thermionic Valve Systems.***—The generation or undistorted transmission of a sinusoidal oscillation by a thermionic valve circuit is, broadly speaking, an impossibility and the suppression of unwanted harmonics is a problem of some significance. A suitably designed filter circuit may precede or follow the valve circuit as a whole. As a recent example may be mentioned the use of a composite filter consisting of a T-section (Fig. a) followed by a derived section (Fig. d) for the effective suppression of the harmonics of a 100 cycles per second supply after amplification by a valve in connection with a high precision A.C. measurement of the absolute unit of resistance.

An interesting application of filters in valve circuits is in the coupling stages of beat frequency oscillators in which a note of audio frequency is produced as the difference tone between two radio frequency oscillations. It is customary to connect the mixing valve to the following low frequency amplifying stages through a low-pass filter, preferably of the composite derived type having a cut-off just above the upper limit of the audio frequencies generated.

In the superhet receivers, the band-pass filter is designed to pass the intermediate frequency on to the I.F. amplifying stages without unwanted oscillations. In this connection and in the development of selective radio receivers generally, the use of coupled oscillatory circuits as a band-pass filter has attracted a great deal of attention. If two identical circuits each consisting of an inductance L and a capacitance C in parallel are coupled by the mutual inductance M, then they will behave as a band-pass filter of which the bounding frequencies of the band-pass are given by $\omega = 1/\sqrt{C(L \pm M)} = \omega_0/\sqrt{L \pm K}$, where ω_0 = resonant frequency of either circuit and K is the coupling co-efficient.

A very interesting and novel type of high quality filter has been developed by Mason and Sykes of the Bell Telephone Laboratory. This consists of a coaxial cable, in which the ratio of reactance to resistance is very high. One filter described for valve coupling and shown in Fig. 9, consists of a length *2l* of cable shunted at its mid-point with a length *l* in which the middle and outer conductors are joined together at the remote end. This is really a multiple band-pass unit in its simple form, but by adding condensers, single band-pass, low-pass, and high-pass filters are obtainable. The cable filters described are used for frequencies ranging from 50 to 150 mega-cycles per second. The high quality of the filters is shown by the fact that one model has a loss at mid-band of only 1·d.b., while the loss at 2 Mc. on either side has increased to 50 d.b.

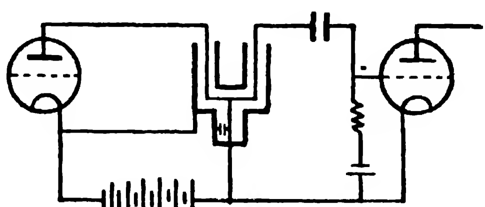
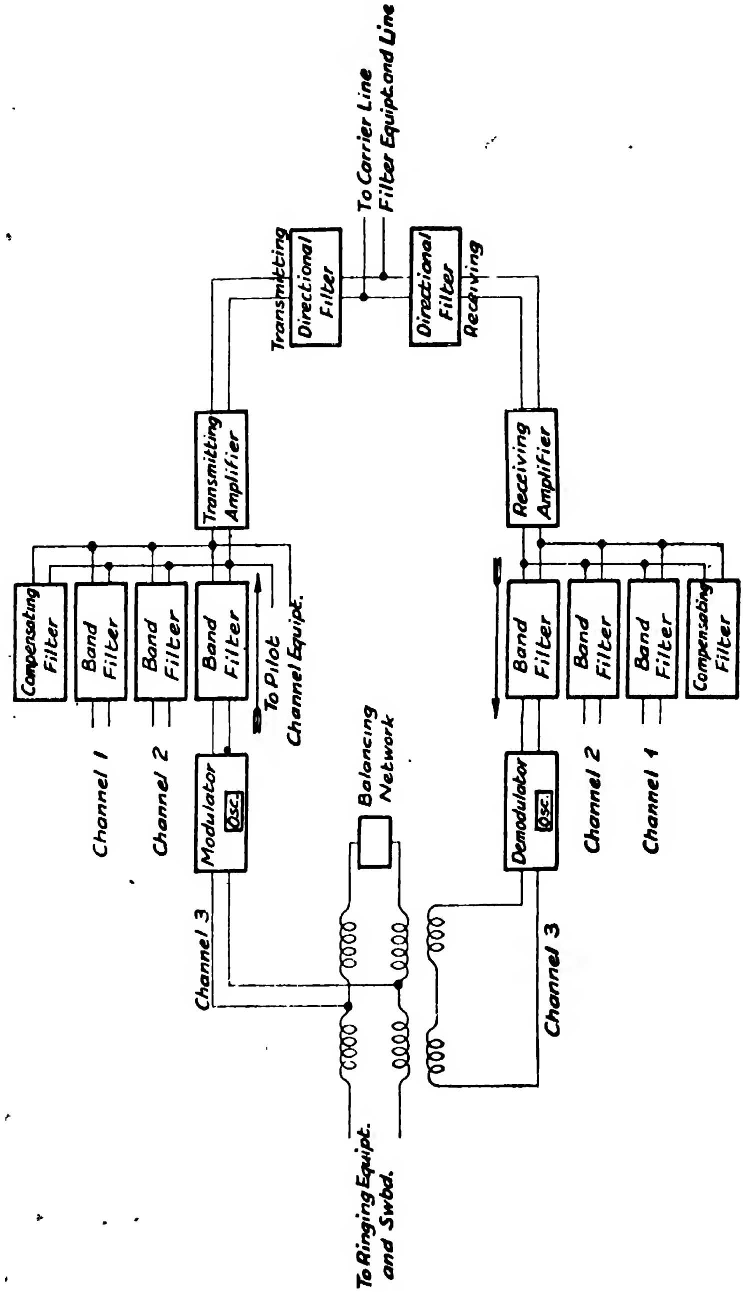


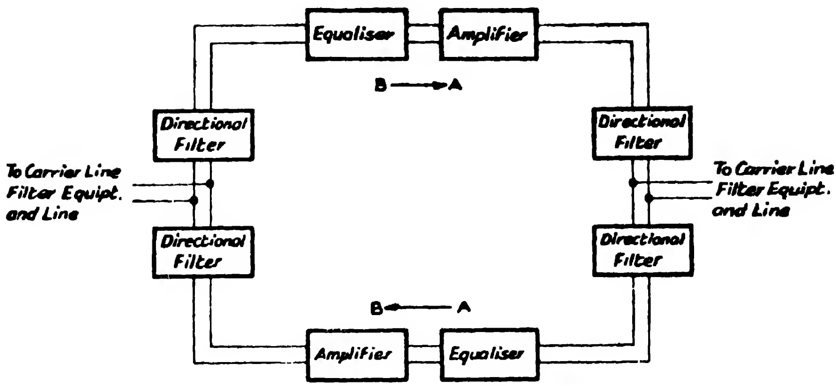
Fig. 9.—Coaxial cable intervalve filter.

3. ***Filters in Carrier Current Telegraphy and Telephony.***— It has been said that "the filter stands beside the vacuum tube as one of the two devices making carrier telegraphy and telephony practicable." In carrier systems, a number of additional telephone and telegraph channels are obtained over one metallic circuit. This is accomplished by modulating a high frequency or "carrier current" with the normal range of voice frequency currents from the usual telephone transmitter. The carrier frequency and the lower side band or the lower side band only is transmitted over the toll line, the other products of modulation being suppressed by electric filters. At the receiving carrier terminal, the various incoming bands of high frequency currents are separated by electric filters and demodulated by the locally generated and rigidly controlled carrier frequency to obtain essentially the original message currents. An idea of the extensive use of the various types of wave filters in carrier systems can be formed by a perusal of the schematic diagrams of a three-channel carrier telephone system shown in Fig. 10 (a), (b) and (c).

4. ***Crystal Wave Filters.***—For a very long time nearly all of the filters developed for telephone transmission systems have been made from combinations of simple inductances and capacitances in ladder or lattice circuit structures or in some derived forms of these. With all such filters the sharpness of cut-off at the edges of the pass-band is dependent on the resistances associated with the filter elements. It is true that the resistance could be made small by making the coils large but this quickly brings in practical difficulties at telephonic frequencies. A possible escape from this limitation is to use in place of an inductance coil a mechanical element coupled to the electric circuit in such a way that its mass or inertia appears in the electric circuit as inductance. A piezo-electric crystal such, for example, as quartz provides just such an element. The piezo-electric effect of these crystals has been known since 1818 when it was discovered by the Curie brothers, but it was not until 1917 that the effect began to receive serious consideration for practical uses. In its use as an oscillator, the quartz crystal with its attached electrodes behaves much as a simple electric circuit comprising an inductance and two capacitances in series. L. Epenschield first suggested that a ladder type filter of sharp cut-off could be made by employing piezo-crystals to supply equivalent inductance without the added resistance inherent in the inductance coils. W.P. Mason

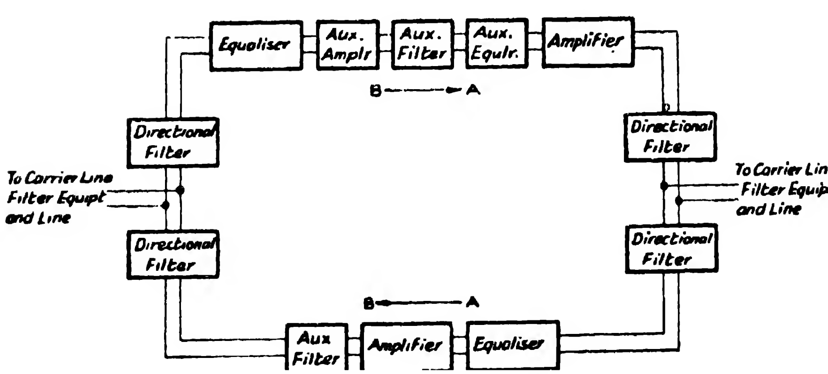


THREE-CHANNEL CARRIER TELEPHONE SYSTEM, TERMINAL EQUIPMENT.
BLOCK SCHEMATIC.
Fig. 10(a)



LOW GAIN REPEATER (TELEPHONE & TELEGRAPH)

Fig. 10(b)



HIGH GAIN REPEATER (TELEPHONE)

Fig. 10(c)

studied the application of crystals to Campbell's lattice-type network in 1929 and found that by adding an inductance in series with each crystal element in the lattice, the ratio of the upper to lower cut-off frequencies could be increased to 1·135. This made the crystal filters a practical device meeting the requirements of a band-pass filter for broad band carrier telephony. Space does not permit our going into more details

of Mason's investigations. A crystal filter unit of the type now in service in multi-channel telephony is shown in Fig. 11 with its attenuation curve.

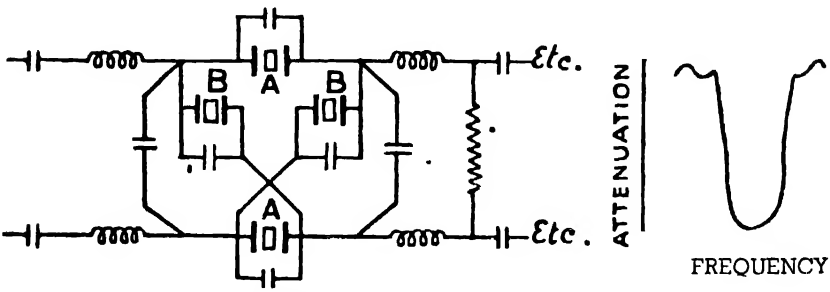


Fig. 11.—Lattice Crystal Filter for Carrier Telephony.

Although four crystals are shown in the above diagram there are only two in reality, those marked AA and BB being actually provided by one crystal with bifurcated electrodes. The crystals are from 2·4 to 4·2 cm. long, about half this of in width and 1/50 in thickness. The electrodes are made by coating the crystal with aluminium by vacuum evaporation. The coils have molybdenum permalloy dust cores.

The crystal filter is also used in more advanced types of superhet receivers. The first detector valve is usually transformer-coupled to a closed circuit of which a single crystal forms a series element. The circuit is capacitatively coupled to an auto transformer forming part of the tuned grid circuit of the first I.F. amplifier valve.

5. ***Magnetostriction Oscillators as Filters.***—The difficulties of producing simple quartz plates for frequencies less than, say, 50 kc./sec. limits the use of crystal filters to higher frequencies. For lower frequencies, H.H. Hall has successfully applied an electro-mechanical system in the magnetostriction oscillator to the production of a 20 kc./sec. filter. Magnetostriction, it may be noted, is the effect shown by a body placed in a magnetic field due to which stresses are produced within the body tending to distort it. Inversely, when a body is distorted, there is a change in the magnetic permeability. Hall used a half-wave rod of Monel metal (a natural alloy of copper and nickel) mounted with a node at its centre and having a coil wound over each half, the one receiving the input and the other supplying the output. The two coils are shielded from each other and the rod is polarized by a permanent magnet.

The coils are coupled only when the rod is in oscillation, the pick-up between them and the vibrator absent, being too small to be measurable. The pass-band was 70 cycles wide at 20 kc./sec., the loss in the transmission band being about 20 d.b. and in the attenuation bands about 60 d.b. The final form adopted uses two rods in series coupled by a valve.

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APPROXIMATE METHOD FOR CALCULATING THE DEFLECTION OF BEAMS

BY

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Synopsis.

Since it is a known fact that deflection often becomes an important factor in the design of Steelwork (*i.e.*, Crane gantry girder, bridge, etc), it is the purpose of this short paper to indicate a simple method by which the deflection at Centre of a beam may be determined for any combination of loads. In order that this method may be presented in the shortest manner, only few cases usually met with in practice have been treated here. Various formulae have been deduced and tables have been prepared so as to save time and labour. Full explanation have been given regarding the use of tables and problems have been solved fully.

Standard Hand Books as well as Text Books on Structural Engineering give formulae for deflection of beams for a few typical and special cases only. But in practice, when it is necessary to calculate the maximum deflection due to partially distributed or several concentrated loads or both on a Beam—either simply supported ; fixed or continuous—a long series of tedious computations are usually necessary.

It can be proved that the point of maximum deflection in a beam of uniform section, loaded in any manner, will be near the centre and not more than 0·0773l from the centre of the span. It is also apparent that the deflection at the centre of the span and the maximum deflection for any type or system of loadings, regardless of the positions on the span, are very nearly equal. Therefore the method outlined here consists of deriving a set of equations which will give an equivalent single load concentrated at the middle for a freely supported beam or at the free end in case of cantilever beam,—which will produce the same amount of deflection. The necessary equations and constants have been obtained from the well-known methods such as (a) double integration or (b) area moment method

1. Designer, Braithwaite & Co., (India) Ltd. Calcutta.

Note.—Written Comments are invited for publication.

usually found in text books. Having determined the equivalent central load by one of the appropriate equations, the deflection is then given by the simple well-known formulae namely :

$$Y_c = \frac{P_c\ l^3}{48EI} \text{ (Simple Beam)}$$

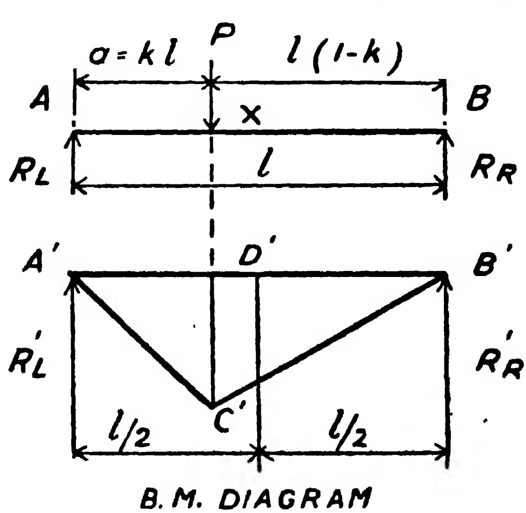
$$Y_b = \frac{P_b\ l^3}{3EI} \text{ (Cantilever Beam)}$$

Notation:—The meanings of symbols used in this article are given below for convenience.

E=Modulus of elasticity *i.e.* 13000 Tons per sq. inch in case of mild steel.
I=Moment of Inertia.
L=Length of beam in feet.
l=Length of beam in inches.
P=Total load either concentrated or distributed in tons.
P_c=Equivalent central load in tons.
P_b=Equivalent load at free end in case of cantilever beam.
Y_c=Deflection at the middle of span in inches.
Y_b=Deflection at free end in case of cantilever span.
M_1=Bending moment in inch tons at one end of span.
M_2=Bending moment in inch tons at the other end of span.
a=Distance from left hand support=kl.
b=Distance from right hand support=$l(1-k)$.
f=Co-efficient.

SIMPLE BEAM.

(A) Simple Beam with a single concentrated load.



$$R_L = \frac{Pl(1-k)}{l}$$

$$P = (1-k)$$

$$R_R = Pk$$

$$\begin{aligned} B.M. &= D'C' \\ &= P(1-k)kl \\ &= Pkl(1-k) \end{aligned}$$

Fig. 1

Consider a simple beam freely supported $A\ B$ shown in Fig. 1 with a single concentrated load P in tons at a distance $= kl$ from A.

Deflection at any point is second moment or moment of the bending moment considering the bending moment as load divided by $E.I.$ or $\frac{d^2y}{dx^2} = \frac{M}{EI}$

Y_c can be calculated either by double integration or taking moment of the moment area to the right of the centre, about the centre.

To obtain R'_R take moment about A

$$\therefore R'_R \times l = \left(\frac{A'D' \times D'C'}{2} \times \frac{A'D'}{3} \right) + \left\{ \frac{D'B' \times D'C'}{2} \times (A'D' + \tfrac{1}{3} B'D') \right\}$$

$$= \left\{ \frac{kl \times Pkl\,(1-k)}{2} \times \frac{2kl}{3} \right\} + \left[\frac{l(1-k) \times Pk\,l(1-k)}{2} + \left\{ kl + \tfrac{1}{3}l\,(1-kl) \right\} \right]$$

$$= \frac{P.k^3l^3\,(1-k)}{3} + \frac{Pkl^2\,(1-k)^2}{6} \times (3kl + l-kl)$$

$$= \frac{Pkl^2}{6}\,(1-k) \left\{ 2k^2l + (1-k) \times (l + 2kl) \right\}$$

$$= \frac{Pkl^3}{6}\,(1-k) \left\{ 2k^2 + 1 + k-2k^2 \right\}$$

$$= \frac{Pkl^3}{6}\,(1-k^2)$$

$$\therefore R'_R = \frac{Pkl^2\,(1-k^2)}{6}$$

$\therefore Y_c =$ moment about centre divided by EI

$$= \left(R'_R \times \frac{l}{2} - \frac{Pk.l}{2} \times \frac{l}{4} \times \frac{l}{6} \right) \div EI$$

$$= \left(\frac{Pkl^3}{6}(1-k^2) \times \frac{l}{2} - \frac{Pkl^3}{48} \right) \div EI$$

$$= \frac{Pkl^3}{48EI}(3-4k^2)$$

In other words Y_c is the deflection at centre of span due to any load P.

Let P_c be load at the centre of span

$\because$ Deflection due to $P_c = \dfrac{P_c l^3}{48EI}$

To get equivalent central load to produce the same deflection at centre

$$\frac{P_c l^3}{48EI} = \frac{Pkl^3}{48EI}(3-4k^2)$$

i.e., for all practical purposes any load P will cause the same deflection as a central load P_c, *if*

$$P_c = Pk\,(3-4k^2)$$

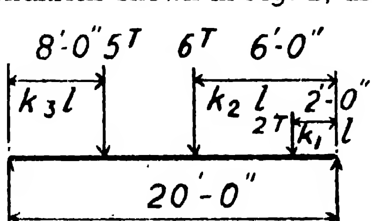
or

$$P_c = Pf_1, \text{ where } f_1 = k\,(3-4k^2) \quad .. \quad .. \quad (1)$$

If the deflection at centre is required due to several concentrated loads on a span, this can be obtained after finding out P_c (for various loads) which is summation of Pf_1 and then applying the standard equation mentioned above. The detail work involved in the solution of problems in the deflection of beams is greatly reduced by means of tables. A few such tables will be given for each particular case. The values of $f_1 = k\,(3-4k^2)$ are given in table 1 for values of k from 0 to $\frac{1}{2}$.

Example illustrating the use of the above table.

Example (1).—Determine the reflection at centre for conditions shown in Fig. 2, using the table 1.



R. S. J. 18"×6"×55lbs.
I = 841·8 in⁴

Fig. 2

$K_1 = \frac{2}{20} = 0{\cdot}1 \qquad \therefore f_1 = 0{\cdot}296$

$K_2 \quad \frac{6}{20} = 0{\cdot}3 \qquad f_1 = 0{\cdot}792$

$K_3 = \frac{8}{20} = 0{\cdot}4 \qquad f_1 = 0{\cdot}944$

Table 1

$$f_1 = k(3-4k^2)$$

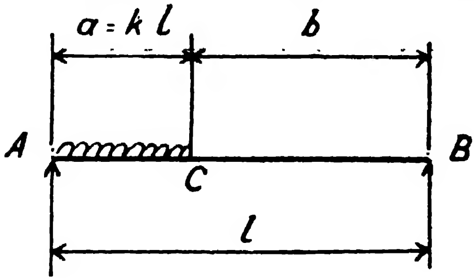
k	f_1	k	f_1	k	f_1	k	f_1	k	f_1
0·01	0·030	0·11	0·325	0·21	0·593	0·31	0·811	0·41	0·954
0·02	0·060	0·12	0·353	0·22	0·617	0·32	0·829	0·42	0·964
0·03	0·090	0·13	0·381	0·23	0·641	0·33	0·846	0·43	0·972
0·04	0·120	0·14	0·409	0·24	0·665	0·34	0·863	0·44	0·979
0·05	0·150	0·15	0·437	0·25	0·688	0·35	0·879	0·45	0·986
0·06	0·179	0·16	0·464	0·26	0·711	0·36	0·893	0·46	0·991
0·07	0·209	0·17	0·490	0·27	0·731	0·37	0·907	0·47	0·995
0·08	0·238	0·18	0·517	0·28	0·752	0·38	0·921	0·48	0·998
0·09	0·267	0·19	0·543	0·29	0·772	0·39	0·933	0·49	0·999
0·10	0·296	0·20	0·568	0·30	0·792	0·40	0·944	0·50	1·000

$$\therefore P_c = \Sigma P f_1 = 2 \times 0{\cdot}296 + 6 \times 0{\cdot}792 + 5 \times 0{\cdot}944$$
$$= 0{\cdot}592 + 4{\cdot}752 + 4{\cdot}720 = 10{\cdot}064 \text{ tons.}$$

$$\therefore Y_c = \frac{P_c . l^3}{48EI}$$
$$= \frac{10{\cdot}064 \times 240 \times 240 \times 240}{48 \times 13000 \times 841{\cdot}8}$$
$$= 0{\cdot}2648 \text{ inches}$$

As a check, it is suggested to the readers to calculate the deflection by ordinary methods given in the text books.

(B) *Simple beam with partial uniform load.*



Total load $= P$

Fig. 3

Consider a simple beam $A\ B$ shown in Fig. 3 with a uniformly distributed load P.

Deflection at centre of span due to load P over a distance $a = kl$.

$$Y \text{ between } C \,\&\, B = \frac{Px}{24EI.l}\left\{2b^2a + 4ba^2 + a^3 - 2x^2a\right\}$$

$$= \frac{Pax}{24EI.l}\left\{2b^2 + 4ba + a^2 - 2x^3\right\}$$

Putting $x = l/_2$

$$= \frac{Pa}{48EI}\left\{2b^2 + 4ba + a^2 - \frac{l^2}{2}\right\}$$

Putting $a = kl$ and $b = l(1-k)$

$$Y_c = \frac{Pkl}{48EI}\left\{2l^2(1-k)^2 + 4kl^2(1-k) + k^2l^2 - \frac{l^2}{2}\right\}$$

$$= \frac{Pkl^3}{48EI}\left\{2(1-k)^2 + 4k(1-k) + k^2 - \tfrac{1}{2}\right\}$$

$$\therefore Y_c = \frac{Pkl^3}{48EI}\left\{2 - 4k + 2k^2 + 4k - 4k^2 + k^2 - \tfrac{1}{2}\right\}$$

$$= \frac{Pkl^3}{48EI}\left\{\frac{3}{2} - k^2\right\}$$

Therefore $\dfrac{P_c l^3}{48EI} = \dfrac{Pl^3k}{48EI}\left(\dfrac{3}{2} - k^2\right)$.

$$\therefore P_c = Pk\left(\frac{3}{2} - k^2\right) \text{ or } P_c = Pf_2$$

where $f_2 = k\left(\dfrac{3}{2} - k^2\right)$ .. .. .. (2)

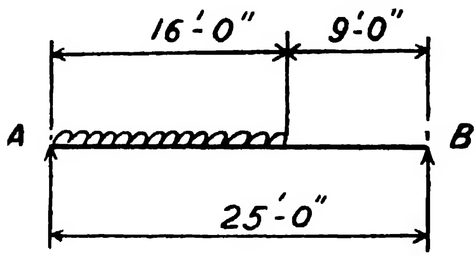
If the uniform load does not extend to the support, the result can be obtained by first assuming the same intensity of load up to the support and subtracting from the resulting deflection that due to the proportionate load just added. If the load extends beyond the centre of the beam, separate deflections should be calculated for loads on each side and results are added.

Table 2

$$f_2 = k(\tfrac{3}{2} - k^2)$$

k	f_2	k	f_2	k	f_2	k	f_2	k	f_2
0·01	0·015	0·11	0·164	0·21	0·306	0·31	0·435	0·41	0·546
0·02	0·030	0·12	0·178	0·22	0·319	0·32	0·447	0·42	0·556
0·03	0·045	0·13	0·193	0·23	0·333	0·33	0 459	0·43	0·565
0·04	0·060	0·14	0·207	0·24	0·346	0·34	0·471	0·44	0·575
0·05	0·075	0·15	0·222	0·25	0·359	0·35	0·483	0·45	0·584
0·06	0·090	0·16	0·236	0·26	0·372	0·36	0·493	0·46	0·593
0·07	0·105	0·17	0·250	0·27	0·385	0·37	0·504	0·47	0·601
0·08	0·120	0·18	0·264	0·28	0·398	0·38	0·515	0·48	0·609
0·09	0·134	0·19	0·278	0·29	0·411	0·39	0·526	0·49	0·617
0·10	0·149	0·20	0·292	0·30	0·423	0·40	0·536	0·50	0·625

***Example* (2).**—Determine the deflection at centre for conditions shown in fig. 4 using table 2.



Load per ft. run=1·5 ton

∴ Total load P=24 tons

$R. S. J.$ 24" × $7\frac{1}{2}$" × 90lbs.

I=2443 in⁴

Fig. 4

In this case first we will find out P_c for the condition of fully loaded span, *i.e.*, from A to B and to obtain the new P_c for partially loaded we will deduct P_c for 9′ 0″ span.

Intensity of load per ft. run = 1·5 tons.

∴ P when the span is fully loaded = 37·5 tons.

$\therefore P_c$ for new Condition $= 0{\cdot}625 \times 37{\cdot}5$

$= 23{\cdot}44$ tons.

k for 9′0″ $= \frac{9}{25} = 0{\cdot}36$

$$\begin{aligned}\therefore P_c &= f_2 \times 9 \times 1{\cdot}5\\ &= 0{\cdot}493 \times 13{\cdot}5\\ &= 6{\cdot}65 \text{ tons}\end{aligned}$$

for 16′0″ Loaded span $= 23{\cdot}44 - 6{\cdot}65$

$= 16{\cdot}79$ tons

$$\therefore Y_c = \frac{16{\cdot}79 \times 300 \times 300 \times 300}{48 \times 13000 \times 2443}$$

$= 0{\cdot}2974$ inches.

Suppose in the above example only 12′ 0″ is uniformly loaded instead of 16′ 0″ as shown in the Fig. 5.

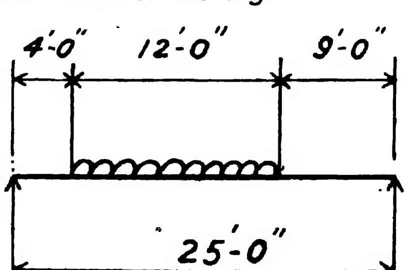


Fig. 5

In the previous example (2) the equivalent central load has been determined and therefore to obtain P_c for 12′ 0″ loaded span the effect of 4′ 0″ loaded span should be deducted.

$k = \frac{4}{25} = 0{\cdot}16$

$\therefore \quad P = 0{\cdot}236 \times 4 \times 1{\cdot}5 = 1{\cdot}416$

$\therefore$ P_c for 1′20″ loaded span $= 16{\cdot}79 - 1{\cdot}416$
$= 15{\cdot}374$ tons

$$\therefore \quad Y_c = \frac{15{\cdot}374 \times 300 \times 300 \times 3000}{48 \times 13000 \times 2443}$$

(C) *Fixed beam with a single concentrated load.*

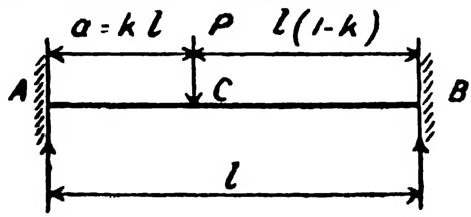


Fig. 6

Consider a fixed beam shown in Fig. 6 with a concentrated load P at C, distance a from left hand support. Deflection y at any point beyond C is equal to

$$\frac{Ra^2}{6EIl^3}\left\{-a\,(2x^3 - 3x^2l + l^3) + 3xl\,(x - l)^2\right\}$$

when $x = l/2$ we will obtain

$$Y_c = \frac{Pa^2}{6EIl^2}\left\{-a\left(2\,\frac{l^3}{8} - \tfrac{3}{4}l^3 + l^3\right) + \frac{3l^2}{2}\left(-\frac{l}{2}\right)^2\right\}$$

$$= \frac{Pa^2}{6EIl^3}\left\{-a\left(\frac{l^3}{2}\right) + \tfrac{3}{8}l^4\right\}$$

Substituting the value of $a = kl$ we obtain

$$Y_c = \frac{Pk^2l^2}{6EIl^3}\left\{-\frac{kl^4}{2} + \tfrac{3}{8}l^4\right\}$$

$$= \frac{Pk^2l^3}{48EI}(3 - 4k)$$

$$\therefore \quad \frac{P_cl^3}{48EI} = \frac{Pl^3k^2}{48EI}(3 - 4k)$$

$$\therefore \quad P_c = Pk^2(3 - 4k)$$
$$= Pf_3 \text{ where } f_3 = k^2(3 - 4k) \qquad \ldots \quad (3)$$

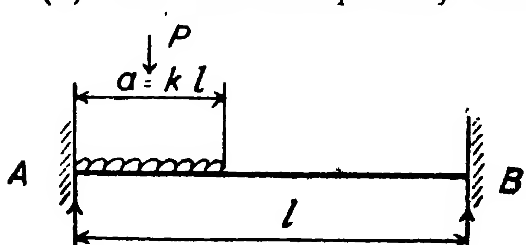
For several loads on the span $P_c = \Sigma P f_3$
Values of f_3 for different values of k are given in table 3.

Table 3

$f_3 = k^2 (3 - 4k)$

k	f_3	k	f_3	k	f_3	k	f_3	k	f_3
0·01	0·0003	0·11	0·301	0·21	0·095	0·31	0·169	0·41	0·229
0·02	0 0012	0·12	0·036	0·22	0·103	0·32	0·176	0·42	0·233
0·03	0·0026	0·13	0·042	0·23	0·110	0·33	0·183	0·43	0·237
0·04	0·0045	0·14	0·048	0·24	0·118	0·34	0·190	0·44	0·240
0·05	0·0070	0·15	0·054	0·25	0·125	0·35	0·196	0·45	0·243
0·06	0·010	0·16	0·060	0·26	0·133	0·36	0·202	0·46	0·245
0·07	0·013	0·17	0·067	0·27	0·140	0·37	0·208	0·47	0·247
0 08	0·017	0·18	0·074	0·28	0·147	0·38	0·214	0·48	0·249
0·09	0·021	0·19	0·081	0·29	0·155	0·39	0·219	0·49	0·2497
0·10	0·026	0·20	0·088	0·30	0·162	0·40	0·224	0·50	0·250

(D) *Fixed beam with partially distributed load.*



Total distributed load = P.

Fig. 7

Deflection at centre, $Y_c = \dfrac{Pa^2}{48EI}(l-a)$

Putting $a = kl$

$$Y_c = \frac{Pk^2l^2}{48EI}(l - kl) = \frac{Pk^2l^3(1-k)}{48EI}$$

$$\therefore \frac{P_c\, l^3}{48EI} = \frac{Pl^3k^2(1-k)}{48EI}$$

$$\therefore P_c = Pk^2(1-k)$$

$$= Pf_4 \text{ centre } f_4 = k^2(1-k) \qquad (4)$$

Values of f_4 for different values of k are given in table 4.

Table 4

$f_4 = k^2(1-k)$

k	f_4	k	f_4	k	f_4	k	f_4	k	f_4
0·01	0·0001	0·11	0·011	0·21	0·035	0·31	0·066	0·41	0·099
0·02	0·0004	0·12	0·013	0·22	0·038	0·32	0·070	0·42	0·102
0·03	0·0009	0·13	0·015	0·23	0·041	0·33	0·073	0·43	0 105
0·04	0·0015	0·14	0·017	0·24	0·044	0·34	0·076	0·44	0·108
0·05	0·0024	0·15	0·019	0·25	0·047	0·35	0·080	0·45	0·111
0·06	0·0034	0·16	0·022	0·26	0·050	0·36	0·083	0·46	0·114
0·07	0·0046	0·17	0·024	0·27	0·053	0·37	0·086	0·47	0·117
0·08	0·0059	0·18	0·027	0·28	0·056	0·38	0·090	0·48	0·120
0·09	0·0074	0·19	0·029	0·29	0·060	0·39	0·093	0·49	0·123
0·10	0·009	0·20	0·032	0·30	0·063	0·40	0·096	0·50	0·125

***Example* (3).**—Calculate the deflection at centre for conditions shown in Fig. 8 for a beam with both ends fixed.

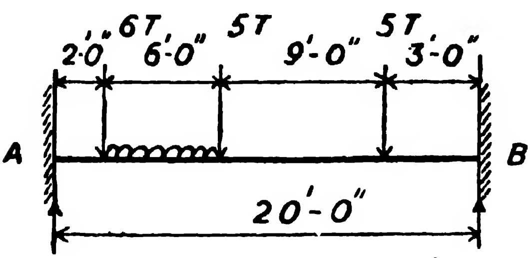


Fig. 8

Distributed Load $= 1{\cdot}5^T$ per ft. run.

Total Distributed Load $= 9{\cdot}0^T$

R.S.J. 18" × 6" × 55lbs.
$I = 841{\cdot}8$ in^4

$P_c = \Sigma\, Pf_3 + P_8 f_4 - P_2 f_4.$

$P_1 = 5{\cdot}0^T$	$k_1 = \frac{3}{20} = 0{\cdot}15$	$f_3 = 0{\cdot}054$	$\therefore\ P_1 f_3$	$= +\ 0{\cdot}270$
$P_2 = 5{\cdot}0^T$	$k_2 = \frac{8}{28} = 9{\cdot}40$	$f_3 = 0{\cdot}224$	$P_2 f_3$	$= +\ 1{\cdot}120$
$P_3 = 6{\cdot}0^T$	$k_3 = \frac{2}{20} = 0{\cdot}10$	$f_3 = 0{\cdot}026$	$P_3 f_3$	$= +\ 0{\cdot}156$
Distributed Load				
$P_8 = 12{\cdot}0^T$	$k_4 = \frac{8}{20} = 0{\cdot}40$	$f_4 = 0{\cdot}096$	$P_8 f_4$	$= +\ 1{\cdot}152$
$P_2 = 3{\cdot}0$	$k_5 = \frac{2}{20} = 0{\cdot}10$	$f_4 = 0{\cdot}009$	$P_2 f_4$	$= -\ 0{\cdot}027$

$\therefore$ Total $P_c = +\ 2{\cdot}671$

$$\therefore\quad Y_c = \frac{2{\cdot}671 \times 240 \times 240 \times 240}{13000 \times 841{\cdot}8 \times 48}$$

$= 0{\cdot}0703$ inches

(*E*) *The effect of bending moment at support on central deflection and determination of equivalent load to produce same deflection at centre.*

Assume moment M_1 at one end of a beam (*Fig.* 9) due to either cantilever load beyond the end or continuous beam or fixed beam.

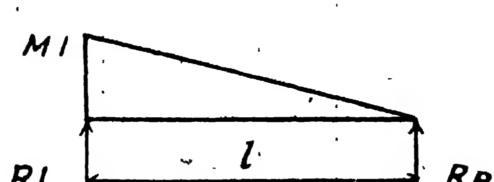


Fig. 9

Following the same method of deduction followed in case A (*i.e.*, the bending moment of 1st bending moment considering as load gives deflection) the results are arrived at as follows :—

$$R_R\, l = \frac{M_1 l}{2} \times \frac{l}{3} \qquad \therefore \quad R_R = \frac{M_1 l}{\;}$$

$$\text{Second Moment at Centre} = \frac{M_1 l}{6} \times \frac{l}{2} - \frac{M_1}{2} \cdot \frac{l}{2} \times$$

$$= \frac{M_1 l^2}{12} - \frac{M_1 l^2}{48} = \frac{M_1 l^2}{16}$$

$$Y_c = \frac{M_1 l^2}{16EI} \text{ If } P_c \text{ is Equivalent Central Load}$$

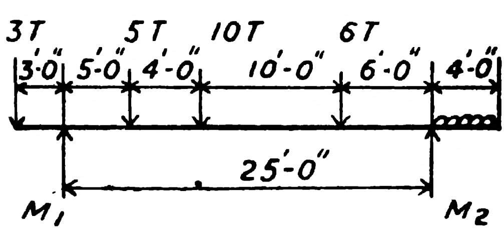
$$Y_c = \frac{P_c\, l^3}{48EI} = \frac{M_1 l^2}{16EI} \text{ i.e. } P_c = \frac{3M_1}{l} \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

It means that the deflection caused at the centre due to bending moment at support is equal to that caused by a load $P_c = \frac{3M_1}{l}$. Similarly if there is an additional moment M_2 at the other end the total equivalent central load

$$P_c = \frac{3\,(M_1+M_2)}{l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Note:—Correct algebraic signs on moment should be applied.

Example (4).—Determine the deflection at the centre for a beam shown in Fig. 10 supporting the system of loadings shown :—



$1{\cdot}5^T$ per ft. ton

R.S.J. 24" × 7½" × 90lbs

$I = 2443$ in.^{4}

Fig. 10

$$M_1 = -\,3 \times 3 = -\,9{\cdot}0 \text{ ft. tons}$$

$$M_2 = \frac{-\,1{\cdot}5 \times 4 \times 4}{2} = -\,12{\cdot}0 \text{ ft. tons}$$

$$P_c = \Sigma\, P f_1 + 3\,\frac{(M_1 + M_2)}{l}$$

$P_1 = 5{\cdot}0^T \qquad k_1 = \frac{5}{25} = 0{\cdot}20 \qquad P_1 f_1 = 5{\cdot}0 \times 0{\cdot}568 = 2{\cdot}84$

$P_2 = 10{\cdot}0^T \qquad k_2 = \frac{9}{25} = 0{\cdot}36 \qquad P_2 f_1 = 10{\cdot}0 \times 0{\cdot}893 = 8{\cdot}93$

$P_3 = 6{\cdot}0^T \qquad k_3 = \frac{6}{25} = 0{\cdot}24 \qquad P_3 f_1 = 6{\cdot}0 \times 0{\cdot}665 = 3{\cdot}99$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad 15{\cdot}76$

$$\frac{3\,({}_1M \times M_2)}{l} = \frac{-3\,(9{\cdot}0 + 1{\cdot}20)}{25} = \frac{63}{25} = -\ 2{\cdot}52 \text{ tons.}$$

$$\therefore\ P = \Sigma\, Pf_1 + 3\,\frac{(M_1 + M_2)}{l}$$

$$= 15{\cdot}76 - 2{\cdot}52 = 13{\cdot}24 \text{ tons.}$$

$$Y_c = \frac{P_c . l^3}{48EI} = \frac{13{\cdot}24 \times 300 \times 300 \times 300}{48 \times 13000 \times 2443} = 0{\cdot}2345 \text{ inches.}$$

(F) *Cantilever beam with a single concentrated load.* For cantilever beams the maximum deflection always occurs at the free end.

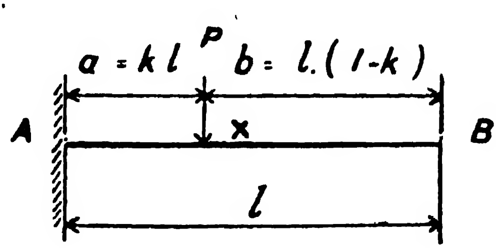


Fig. 11

It can be found by double integration that

$$Y_b = \frac{Pl^3k^2}{6EI}\,(3-k)$$

The same formula would be applicable to any number of loads and for different value of P and k. If P_b is an equivalent concentrated load at B,

$$Y_c = \frac{P_b \times l^3}{3E1}$$

$$\therefore \quad \frac{P_b\, l^3}{3E1} = \frac{Pl^3k^2}{6E1}\,(3-k)$$

$$\therefore \quad P_b = \frac{Pk^2}{2}\,(3-k)$$

$$= Pf_5$$

$$\text{where } f_5 = \frac{k^2}{2} \quad (3-k) \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Table 5

$$f_5 = \frac{k^2}{2}(3-k)$$

k	f_5	k	f_5	k	f_5	k	f_5
0·01	·00015	0·26	0·0926	0·51	0·3238	0·76	0·647
0·02	0·0006	0·27	0·0995	0·52	0·3353	0·77	0·661
0·03	0·0013	0·28	0·1066	0·53	0·3469	0·78	0·675
0·04	0·0024	0·29	0·1140	0·54	0·3586	0·79	0·689
0·05	0·0037	0·30	0·1215	0·55	0·3706	0·80	0·704
0·06	0·0053	0·31	0·1292	0·56	0·3826	0·81	0·718
0·07	0·0072	0·32	0·1372	0·57	0·3948	0·82	0·733
0·08	0·0093	0·33	0·1454	0·58	0·4070	0·83	0·747
0·09	0·0118	0·34	0·1537	0·59	0 4195	0·84	0·762
0·10	0·0145	0·35	0·1623	0·60	0·4320	0·85	0·777
0·11	0·0175	0·36	0·1711	0·61	0·445	0·86	0 791
0·12	0·0207	0·37	0·180	0·62	0·458	0·87	0·806
0·13	0·0242	0·38	0·1892	0·63	0·470	0·88	0·821
0·14	0·0280	0·39	0·1985	0·64	0·483	0·89	0·836
0·15	0·0320	0·40	0·208	0·65	0·496	0·90	0·850
0·16	0·0363	0·41	0·2177	0·66	0·510	0·91	0·865
0·17	0·0409	0·42	0·2276	0·67	0·523	0·92	0·880
0·18	0·0457	0·43	0·2376	0·68	0·536	0·93	0·895
0·19	0·0507	0·44	0·2478	0·69	0·550	0·94	0·910
0·20	0·0560	0·45	0·2582	0·70	0·563	0·95	0·925
0·21	0·0615	0·46	0·2688	0·71	0·577	0·96	0·940
0·22	0·0673	0·47	0·2794	0·72	0·591	0·97	0·955
0·23	0·0732	0·48	0·2903	0·73	0·605	0·98	0·970
0·24	0·0795	0·49	0·3013	0·74	0·619	0·99	0·985
0·25	0·086	0·50	0·3125	0·75	0·633	1·00	1·00

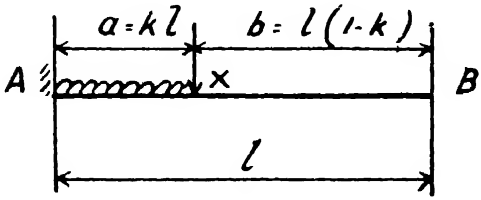
For a number of loads for different values of k, the formula in page 352 may be written

$$P_b = \Sigma\, Pf_5.$$

Note.—The value of k in this particular case will vary from 0 to unity.

Values of f_5 for different values of k are given in table 5.

(G) *Cantilever beam with partial uniformly distributed load as shown in Fig. 12.*



Total load.

Fig. 12

If the load only extends to a distance $a = kl$ from the fixed end A, the deflection at the free end B can be determined by the double integration method.

$$\therefore\ Y_b = \frac{Pl^3k^2}{24EI}(4 - k)$$

If P_b be equivalent concentrated load at free end

$$Y_b = \frac{P_bl^3}{3EI} = \frac{Pl^3k^2}{24EI}(4 - k)$$

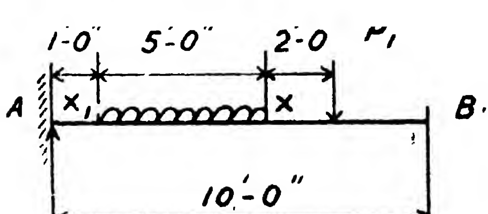
$$\therefore\ P_b = \frac{k^2}{8}(4 - k)$$

$$Pf_6$$

$$\text{where } f_6 = \frac{k^2}{8}(4 - k). \qquad (8)$$

Values of f_6 for different values of k are given in table 6.

***Example* (5).**—Calculate the deflection at the free end for conditions shown in Fig. 13 using Tables 5 and 6.



$L = 10' - 0''$
$P_1 = 2$ tons.
w = Distributed Load say 1 ton per ft. run.
R. S. J. 16″×6″×50 lbs.
$I = 618{\cdot}1$ in^4

Fig. 13

Table 6

$$f_6=\frac{k^2}{8}(4-k)$$

k	f_6	k	f_6	k	f_6	k	f_6
0·01	0·00005	0·26	0·0316	0·51	0·1135	0·76	0·2339
0·02	0·0002	0·27	0·0340	0·52	0·1176	0·77	0·2393
0·03	0·0004	0·28	0·0365	0·53	0·1218	0·78	0·2449
0·04	0·0008	0·29	0·0390	0·54	0·1261	0·79	0·2504
0·05	0·0012	0·30	0·0416	0·55	0·1304	0·80	0·2560
0·06	0·0018	0·31	0·0443	0·56	0·1349	0·81	0·2616
0·07	0·0024	0·32	0·0471	0·57	0·1394	0·82	0·2673
0·08	0·0032	0·33	0·0499	0·58	0·1438	0·83	0·2730
0·09	0·0040	0·34	0·0529	0·59	0·1484	0·84	0·2787
0·10	0·0050	0·35	0·0590	0·60	0·1530	0·85	0·2845
0·11	0·0060	0·36	0·0590	0·61	0·1576	0·86	0·2903
0·12	0·0070	0·37	0·0621	0·62	0·1624	0·87	0·2961
0·13	0·0082	0·38	0·6054	0·63	0·1672	0·88	0·3020
0·14	0·0095	0·39	0·0686	0·64	0·1720	0·89	0·3080
0·15	0·0108	0·40	0·0720	0·65	0·1769	0·90	0·3140
0·16	0·0123	0·41	0·0754	0·66	0·1819	0·91	0·3208
0·17	0·0138	0·42	0·0789	0·67	0·1869	0·92	0·326
0·18	0·0155	0·43	0·0825	0·68	0·1919	0·93	0·332
0·19	0·0172	0·44	0·0862	0·69	1·1970	0·94	0·338
0·20	0·0190	0·45	0·0898	0·70	0·2021	0·95	0·344
0·21	0·0209	0·46	0·0936	0·71	0·2073	0·96	0·350
0·22	0·0229	0·47	0·0975	0·72	0·2126	0·97	0·356
0·23	0·0249	0·48	0·1014	0·73	0·2178	0·98	0·363
0·24	0·0271	0·49	0·1053	0·74	0·2232	0·99	0·369
0·25	0·0293	0.50	0·1094	0·75	0·2285	1·00	0·375

In order to calculate P_b due to distributed load from X_1 to X it is necessary first calculate P_b for A to X and deduct P_b for A to X_1

Total Load A to $X = 6 \times 1{\cdot}0$ ton say Px

,, ,, A to $X = 1 \times 1{\cdot}0$,, ,, Px_1

$\therefore P_b = P_1 f_5 + Pxf_6 - Px_1 f_6$

$P_1 = 2{\cdot}0\ k = \frac{8}{10} = 0{\cdot}8 \quad f_5 = 0{\cdot}704 \therefore P_1 f_5 = +\ 1{\cdot}408$

$Px = 6{\cdot}0\ k = \frac{6}{10} = 0{\cdot}6 \quad f_6 = 0{\cdot}153 \quad Pxf_6 = +\ 0{\cdot}918$

$Px_1 = 1{\cdot}0\ k = \frac{1}{10} = 0{\cdot}1 \quad f_7 = 0{\cdot}005 \quad Px_1 f_6 = -\ 0.005$

$\therefore$ Total $P_b = +\ 2{\cdot}321$ tons.

$$Y_b = \frac{2{\cdot}321 \times 120 \times 120 \times 120}{3 \times 13000 \times 618{\cdot}1}$$

$= 0{\cdot}1664$ Inches.

***Example* (6).**—Calculate moment at fixed end, reactions, and deflection at the centre for a beam fixed at one end, and supported freely at the other end as shown in Fig. 14.

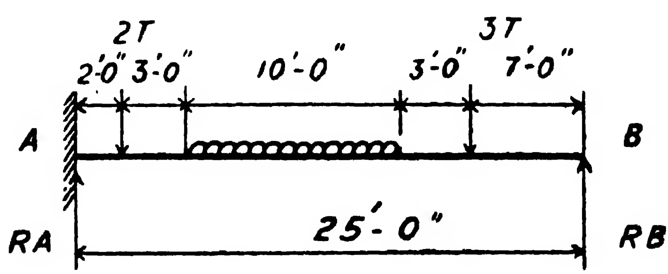


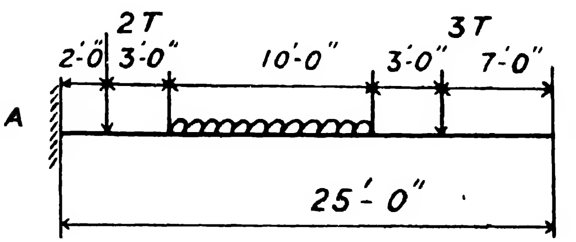
Fig. 14

Distributed load say 1 ton per ft. run.

This beam will be treated as a cantilever first and P_b at free end will be calculated. The deflection will be zero if there is support at B. Therefore, P_b is equal to R_b. This P_b can be determined by use of tables 5 & 6 as shown in previous example, after knowing R_b which is equal to P_b bending moment and reaction at fixed end, *i.e.*, at A can be calculated very easily.

After knowing fixed end moment, the beam should be treated as a simple span and P_c should be calculated at the centre of beam after making an allowance for the fixed end moment. When P_c is known, the deflection as usual should be determined.

The example given on the previous page will illustrate the method of procedure for finding out central deflection more clearly.



As a cantilever beam.

Fig. 15

$P_1 = 2{\cdot}0 \qquad k_1 = \frac{2}{25} = 0{\cdot}08 \qquad f_5 = 0{\cdot}0093 \qquad P_1 f_5 = +\,0{\cdot}0186$

$P_2 = 3{\cdot}0 \qquad k_2 = \frac{18}{25} = 0{\cdot}72 \qquad f_5 = 0{\cdot}591 \qquad P_2 f_5 = +\,1{\cdot}7730$

Distributed Load

$P_3 = 15{\cdot}0 \qquad k_3 = \frac{15}{25} = 0{\cdot}60 \qquad f_6 = 0{\cdot}153 \qquad P_3 f_6 = +\,2{\cdot}2950$

$P_4 = 5{\cdot}0 \qquad k_4 = \frac{5}{25} = 0{\cdot}20 \qquad f_6 = 0{\cdot}019 \qquad P_4 f_6 = +\,0{\cdot}0950$

$\therefore$ Total $P_b = +\,3{\cdot}9916$ tons.

$\therefore Rb = 3{\cdot}99$ Tons.

$Ra = 2 + 3 + 10 - 3{\cdot}99 = 11{\cdot}01$ Tons.

B.M. At A $= 3{\cdot}99 \times 25{\cdot}0 - 3{\cdot}0 \times 18{\cdot}0 - 10{\cdot}0 \times 10{\cdot}0 - 2{\cdot}0 \times 2{\cdot}0 = 99{\cdot}75 - 54{\cdot}0 - 100{\cdot}0 - 4{\cdot}0$

B.M. at A $= -\,58{\cdot}25$ ft. tons.

Total distributed load = 10 tons.

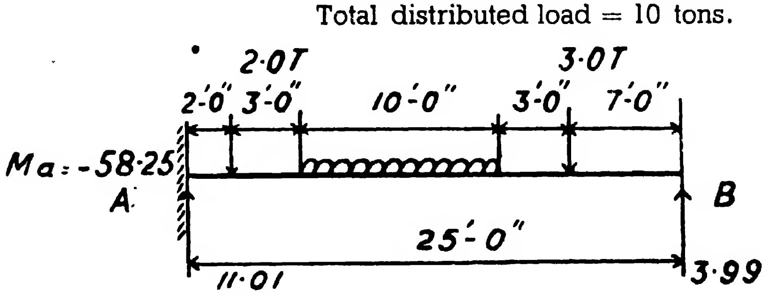


Fig. 16

R.S.J. 20" × 6½" × 65 lbs.
$I = 1226$ in^4

P = Due to concentrated load + due to distributed load + effect of *Ma*.

(1) Due to concentrated load.

$P_1 = 2{\cdot}0$	$k_1 = \frac{2}{25} = 0{\cdot}08$	$f_1 = 0{\cdot}238$	$\therefore\ P_1 f_1 = 0{\cdot}476$
$P_2 = 3{\cdot}0$	$k_2 = \frac{7}{25} = 0{\cdot}28$	$f_1 = 0{\cdot}752$	$\therefore\ P_2 f_1 = 2{\cdot}256$
			$2{\cdot}732$

(2) Distributed Load.

$P_2 = 25{\cdot}0$ (fully loaded)	$k_3 = \frac{12{\cdot}5}{25} = 0{\cdot}5$	$f_2 = 0{\cdot}625$	$P_3 f_2 = \quad 15{\cdot}625$
$P_4 = 5{\cdot}0$	$k_4 = \frac{5}{25} = 0{\cdot}2$	$f_2 = 0{\cdot}292$	$P_4 f_2 = -\ 1{\cdot}460$
$P_5 = 10{\cdot}0$	$k_5 = \frac{10}{25} = 0{\cdot}4$	$f_2 = 0{\cdot}536$	$P_5 f_2 = -\ 5{\cdot}360$
			$+\ 8{\cdot}805$

(3) Due to bending moment.

$$\therefore \text{ Effect} = \frac{3 \times 58{\cdot}25 \times 12}{300}$$

$$= \frac{3 \times 58{\cdot}25}{25} = -\ 6{\cdot}99 \text{ Tons.}$$

$$\therefore \text{ Total } P_c = 2{\cdot}73 + 8{\cdot}80 - 6{\cdot}99$$

$$= 4{\cdot}54 \text{ Tons.}$$

$$\therefore\ Y_c = \frac{4{\cdot}54 \times 300 \times 300 \times 300}{48 \times 13000 \times 1226} = 0{\cdot}1602 \text{ inches.}$$

Deflection of continuous beam having equal moment of inertia.

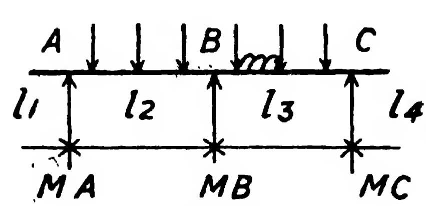


Fig. 17

First it will be necessary to calculate the bending moments by usual methods. P_c for each span considering as a simple beam with both ends free should be determined as worked out before in pervious examples. The allowance should be made for bending moment at supports.

$\therefore$ Final $P_c = P_c + \dfrac{3\,(Ma + Mb)}{l}$ for span l_2.

$\because$ Deflection at centre say for span l_2 is equal to

$$\frac{\text{Final } P_c \times l_2^3}{48EI}$$

***Example* (7).**—Consider a beam on three supports and equal spans as shown in the Fig. 18 and determine the reactions bending moment at support and respective deflection at centre of each span.

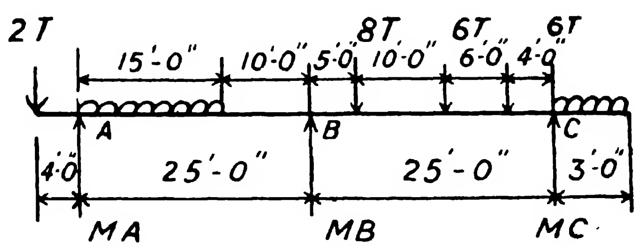


Fig. 18

$R.J.S. = 24'' \times 7\tfrac{1}{2}'' \times 100$ lbs. $I = 2654$ in^4

Distributed load say 2 tons per ft. run.

First consider a simple beam A to C with over hang and determine P_c which is equal to reaction at B.

$$Ma = -\ 8{\cdot}0 \text{ ft· tons.}$$

$$Mc = -\ \frac{2 \times 3 \times 3}{2} = -\ 9{\cdot}0 \text{ ft. tons·}$$

Computation of the equivalent central load is as follows:—

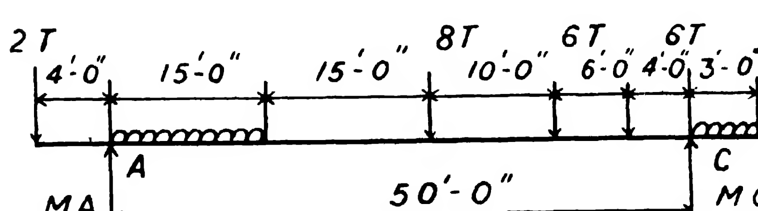


Fig. 19

$P_1 = 6^T \quad k_1 = \frac{4}{50} = 0{\cdot}08 \quad f_1 = 0{\cdot}238 \quad P_1 f_1 = 0{\cdot}238 \times 6 = 1{\cdot}428$

$P_2 = 6^T \quad k_2 = \frac{10}{50} = 0{\cdot}20 \quad f_1 = 0{\cdot}568 \quad P_2 f_1 = 0{\cdot}568 \times 6 = 3{\cdot}408$

$P_3 = 8^T \quad k_3 = \frac{20}{50} = 0{\cdot}40 \quad f_1 = 0{\cdot}944 \quad P_3 f_1 = 0{\cdot}944 \times 8 = 7{\cdot}552$

Distributed Load.

$P_4 = 30^T \quad k_4 = \frac{15}{50} = 0{\cdot}30 \quad f_2 = 0{\cdot}423 \quad P_4 f_2 = 0{\cdot}423 \times 30 = 12{\cdot}690$

$25{\cdot}078$

Allowance for Ma and $Mc = -\left(\frac{8{\cdot}0 + 9{\cdot}0}{50}\right) \times 3 = \frac{51}{50} = 1{\cdot}02$

$\therefore$ Nett $P_c = 25{\cdot}078 - 1{\cdot}02 = 24{\cdot}058$ Tons.

$\therefore Rb = 24{\cdot}058$ Tons.

Take moment about c in order to get Ra (See Fig. 18)

$$\therefore Ra \times 50 + Rb \times 25 = 2 \times 54{\cdot}0 + 30 \times 42{\cdot}5 + 8 \times 20{\cdot}0 + 6 \times 10{\cdot}0 + 6 \times 4{\cdot}0 - \frac{2 \times 3^2}{2}$$

$$\therefore Ra \times 50 + 24{\cdot}058 \times 25 = 108{\cdot}0 + 1275{\cdot}0 + 160{\cdot}0 + 60{\cdot}0 + 24{\cdot}0 - 90{\cdot}0$$

$\therefore Ra \times 50 = 1016{\cdot}55$

$\therefore Ra = 20{\cdot}33$ Tons.

$\therefore Rc = 2 + 30 + 8 + 6 + 6 - 24{\cdot}058 - 20{\cdot}33 + 6{\cdot}0_T$

$= 58{\cdot}0 - 44{\cdot}388$

$= 13{\cdot}612$ Tons.

$Mb = 20{\cdot}33 \times 25 - 2 \times 29{\cdot}0 - 30 \times 17{\cdot}5$

$= -74{\cdot}75$ ft. tons. (See Fig. 18)

Computation for deflection at centre of $A\ B$ and $B\ C$. First consider the span A B as fully loaded.

$\therefore P_c = 2 \times 25 \times 0{\cdot}625 = 31{\cdot}25$ Tons.

Deduction for 10′—0″

$P_2 = 2 \times 10 = 20^T \quad k = \frac{10}{25} = 0{\cdot}4 \quad f_2 = 0{\cdot}536$

$\therefore P_2 f_2 = 0{\cdot}536 \times 20 = 10{\cdot}72^T$

Deduction due to bending moment $= 3\left(\frac{Ma + Mb}{l}\right)$

$$= 3\left(\frac{8 + 74{\cdot}75}{25}\right)$$

$$= 9{\cdot}93 \text{ Tons.}$$

$$\therefore \text{Final } P_c = 31{\cdot}25 - 10{\cdot}72 - 9{\cdot}93$$

$$= 10{\cdot}60 \text{ Tons.}$$

$$\therefore Y_c = \frac{10{\cdot}60 \times 300 \times 300 \times 300}{48 \text{ EI}}$$

$$= \frac{10{\cdot}60 \times 300 \times 300 \times 300}{48 \times 13000 \times 2654}$$

$$= 0{\cdot}1728 \text{ Inches.}$$

Consider span BC.:—

$P_1 = 8^T$	$k_1 = \frac{5}{25} = 0{\cdot}2$	$f_1 = 0{\cdot}568$	$P_1\ f_1 = 4{\cdot}544$
$P_2 = 6^T$	$k_2 = \frac{10}{25} = 0{\cdot}4$	$f_1 = 0{\cdot}944$	$P_1\ f_1 = 5{\cdot}664$
$P_3 = 6^T$	$k_3 = \frac{4}{25} = 0{\cdot}16$	$f_1 = 0{\cdot}464$	$P_3\ f_1 = 2{\cdot}784$
			$12{\cdot}992$

Deduction for bending moment $= -3\left(\frac{74{\cdot}75 + 9{\cdot}0}{25}\right)$

$$= -10{\cdot}05 \text{ Tons.}$$

$$\therefore P_c = 12{\cdot}992 - 10{\cdot}05$$

$$= 2{\cdot}942 \text{ Tons.}$$

$$\therefore Y_c = \frac{2{\cdot}942 \times 300 \times 300 \times 300}{48 \times 13000 \times 2654}$$

$$= 0{\cdot}0479 \text{ inches.}$$

When the distribution of load is irregular the deflection at the centre can be obtained by considering the loads as consisting of several loads, either concentrated or distributed. The result thus obtained will be practically the same.

Special cases.

(1)

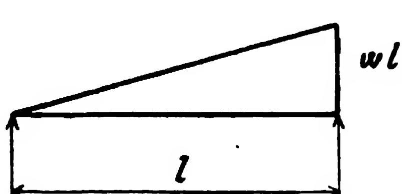


Fig. 20

Say varying load from 0 to wl

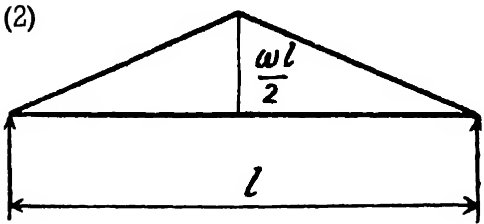
$$\therefore \text{Total load} = \frac{wl^2}{2} = \text{say } P.$$

$P_c = \text{Factor} \times P$

$= 0{\cdot}625 \times P$

$$\therefore Y_c = \frac{0{\cdot}625 \times P \times l^3}{48EI} \quad \ldots \quad \ldots \quad (9)$$

(2)



Total load P

Fig. 21

$\therefore = 0{\cdot}800 \times P$

$$Y_c = \frac{0{\cdot}800 \times P \times l^3}{48EI} \quad \ldots \quad (10)$$

In conclusion it can be noted that the time required for the approximate solution of problems for computing the deflection of beams is greatly reduced by means of tables and methods given above while exact solution will take a considerable time.

The Author is indebted to Messrs. H. W. T. Hain, R. J. C. Tweed and H. Allan of Messrs. Braithwaite & Co., (India) Ltd. for the interest they have taken and for the facilities they have provided. His thanks are also due to his cousin Mr. K. C. Desai for his valued assistance in checking tables of this paper.

GRAPHICAL REPRESENTATION OF COMPARATIVE ECONOMICS OF HYDRO-ELECTRIC *versus* THERMAL INSTALLATIONS

BY

S. T. PROKOFIEFF,[1] *Member.*

Synopsis

The Author suggests that Graphical representation of the comparative economics would fairly indicate economical soundness of an Hydro-electric installation especially in the preliminary stages.

It is assumed that the chief competitor of water power is "steam" in modern power plants, as Diesel engine in spite of its superior thermal efficiency is incapable of competing with a modern steam turbine plant.

The Author indicates on comparative basis *the annual charges of the* competing plants and shows various advantages *in favour of Hydro-electric* Installations.

In the course of the investigations and survey conducted by the Author in Gwalior State on Water Power possibilities, it occured to the Author to represent graphically the economics of Hydro-Electric Installations as compared with Thermal Installations.

Although every particular proposal must naturally be judged on its own merits and comparative calculations must be made to justify the capital outlay required for Hydro-Electric Development (as compared with Thermal Generation) the graphical representation of the comparative economics would enable both the investigator and the administrator called upon for judgment to form a fair idea of the economical soundness of a proposal, especially in the preliminary stages.

As will be seen the graphical representation brings forth the basic factors so clearly that it makes Hydro-Electric Development advantageous.

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Note :—Written Comments are invited for publication.

Large capital expenditure is usually necessary for civil work in connection with Hydro-Electric Development as well as, normally, a long main transmission line is required, as water power must be developed where it is found. Against the high capital cost in a water power installation is set mainly the cost of fuel in a thermal plant. But here the matter does not end. Only when all the annual charges are calculated and other factors evaluated, a fair comparison can be made.

The chief competitor of water power is steam in modern power plants, as no Diesel plant even with its superior thermal efficiency is capable of competing with the modern steam turbine plants of the sizes under consideration. (See "The Hydro-Electric Practice in India" by Prof. B. C. Chatterjee).

To evaluate the comparative annual charges let us use the following abbreviations :—

Let B	=	capacity of installation.
a	=	unit cost of thermal plant (Machinery).
Thus aB	=	the total cost of thermal plant (Machinery).
a′	=	unit cost of Hydro-Electric plant (Machinery).
Let 10%	=	loss of power in transmission and transformation.
Thus 1·1 a′B	=	the total cost of Hydro-Electric Plant (Machinery).
b	=	unit cost of Civil Works in connection with thermal plant.
Thus bB	=	the total cost of the same.
X	=	total cost of Civil Works and main transmission line of Hydro-Electric Plant.
c%	=	interest charges (equal in both cases).
d%	=	depreciation charges for power plant.
e%	=	maintenance charges for power plant.
f%	=	maintenance charges for Civil Works.
g	=	in annas—the cost of fuel per electrical unit—sent out (dependant on the size of plant and the load factor).
l%	=	Load factor of plant.

Supervision charges are taken equal in both cases.

Then:

Total annual charges (except supervision) for thermal plant in Rupees would be

$$\cdot oc(a+b)B + \cdot od \times aB + \cdot oe \times aB + \cdot of \times cB$$

$$+ \frac{1}{16} g \times \cdot ol \times 24 \times 365 \times B \qquad \text{(i)}$$

Total annual charges for Hydro-Electric Plant in Rupees would be :—

$$\cdot oc\,(1\cdot 1\,a'B + X) + \cdot od \times 1\cdot 1\,a'B + \cdot oe \times 1\cdot 1\,a'B + \cdot of\,X \qquad (ii)$$

Equating the two expressions we have :—

$$B\left\{\cdot oc\,(a+b) + \cdot od \times a + \cdot oe \times a + \cdot of\,b + \frac{g \times \cdot o\,l \times 8760}{16}\right\}$$

$$= X(\cdot oc + \cdot of) + 1\cdot 1B\,(\cdot oc \times a' + \cdot od \times a' + \cdot oe \times a')$$

$$X = \frac{B}{\cdot oc + \cdot of}\left\{a\,(\cdot oc + \cdot od + \cdot oe) + b\,(\cdot oc + \cdot of)\right.$$

$$\left. + 5\cdot 475\,g \times l - 1\cdot 1\,a'(\cdot oc + \cdot od + \cdot oe)\right\} \qquad (iii)$$

X—represents the maximum investment in civil works and main transmission line in connection with Hydro-Electric plant which may be justified in competition with thermal plant.

Working out numerical examples for the plants of different capacities between 500 KW. and 5000 KW and for varying load factors (20%, 50% and 100%), the Author has compiled the "Border Line" curves (See Page 372).

In the above equation g is a function of B as the fuel consumption depends on the plant's capacity and l (load factor) is another variable. The equation thus being of the type

$$X = y\left\{C + f(y, z)\right\}$$

Where X — is the cost under consideration.

y — the plant capacity.

C — constant.

f (y, z) — function of the plant capacity and the variable load factor the equation is expressed by curved lines.

The several assumptions made are to be explained. It has been the intention of the Author to assume fair costs and charges to suit the conditions of the proposals under investigation in Gwalior State, even if slightly exaggerating in favour of thermal power so as to make the competition somewhat stiffer for Hydro-Electric Plants.

As regards the coal consumption varying with the size of plant and load factor, the following diagram is reproduced from the report, of the Hydro-Electric Power Commission of Ontario.

COAL CONSUMPTION ACCORDING TO PLANTS SIZE & LOAD FACTOR (H.E.P.C. ONTARIO)

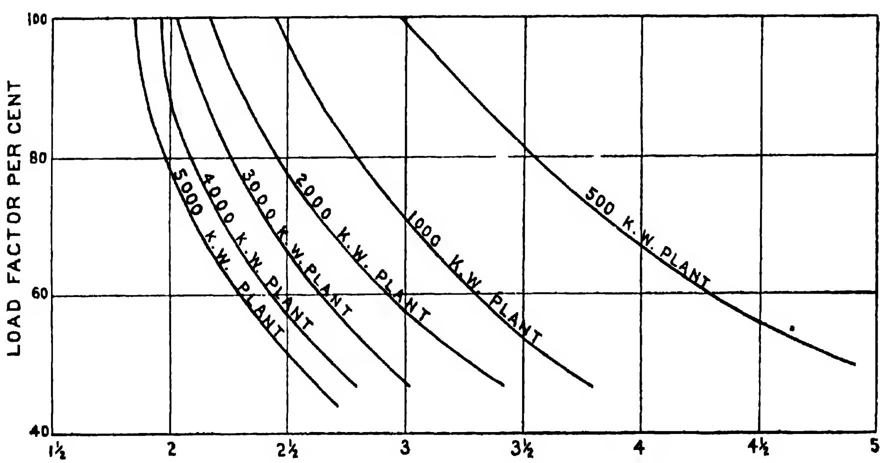


Fig. 1.

COAL POUNDS PER UNIT (kWh)

The data given in the tables of fuel consumption of generating stations in Great Britain in "Electrical Engineering Practice" by J. W. Meares and R. E. Neale, as also different other data, obtainable in modern power plants in India have been consulted.

Amongst the information obtained that from the new Mulajore Generating Station (capacity: Three 30000 kW Sets) shows the coal consumption per unit generated at 1·27 lbs. (load factor not stated).

The Kalyan Thermal Power Station of G. I. P. Rly. (4 units of 10000 kW each) reports actual cost of fuel (including oil fuel) at As. ·1431 per unit with C.P. coal at an average pitsmouth price of Rs. 3-2-0 per ton, information being insufficient for working out the coal consumption per unit.

The assumption made by the Author for construction of the "Border Line" curves are shown in the following table :—

LBS. OF COAL PER ELECTRICAL-UNIT (kWh) SENT OUT

Size of plant in kW.	Load factor.		
	20%	50%	100%
500	5·5 } Under-	3·5	2·5
2000	4·5 } estimated.	3·25	2·25
5000	3·75	2·75	1·75

The cost of coal (Bengal, 12000 B.Th.U/lb.) is assumed at Rs. 15/- per ton, the pre-present-War rate obtainable in Gwalior.

As regards the unit cost of plant (to include generating machinery and electric equipment) recent (pre-present-War of course) data have been compared and assumptions made as below for the comparatively low heads of the Hydro-Electric installations (from 30 to 80 feet) under investigation in Gwalior at present.

Utilization of variable heads of water stored behind dams necessitated consideration of variable head Turbines (Kaplan Wheels) for which higher unit costs are assumed.

ASSUMED UNIT COST OF PLANT (MACHINERY)

Plant's capacity in KW.	Thermal plant.	HYDRO-ELECTRIC PLANT.	
		Constant Head Turbines.	Variable Head Turbines.
IN RUPEES.			
500	500	300	400
2000	250	200	350
5000	225	187 5	325

The cost of civil works in thermal plants is assumed at Rs. 50/- per KW (this to include all foundations and structures for power and boiler plant, for coal handling installation and cooling water installation, etc.)

Power losses in main transmission line are assumed at 10%.

As regards the different charges, the supervision charges are assumed equal in both cases and are not therefore entering our calculation.

The interest charges are assumed at 4%, as against $3\frac{1}{2}$% suggested by Sir William Stampe in his recommendations submitted to the State authorities.

A net return of 3·95% on the capital outlay is reported for the year ending March, 1939, by U.P. Hydro-Electric Grid Scheme. The net return on Pykara Hydro-Electric System is shown at 7·4% in the Administration Report for 1938-39 and that of Mettur H. E. System at 2·3% after the first year operation.

Depreciation charges on machinery (inclusive of electric equipment) is assumed at 4% as also on transmission line (exaggerated).

Maintenance (and repair) charges have been assumed at 1% on machinery (inclusive of electric equipment) and transmission line.

Similarly, *1*% charges are assumed for maintenance and repair of civil works (exaggerated in case of dams and alike).

DEDUCTIONS FROM EXAMINATION OF THE "BORDER LINE" CURVES:

1. ***Numercial Examples :***

Capacity kW.	Load factor.	Type	Approx : Investment justifiable on civil works and transmission line of Hydro-Electric installations.
500	100%	Constant Head Turbine.	Nearly Rs. 17 Lakhs.
1000	50%	Variable Head	About Rs. 19 Lakhs
2000	50%	Constant Head.	Rs. 41½ Lakhs
5000	20%	Variable Head.	Rs. 35½ Lakhs

2. The influence of the size of plant (other conditions being equal) is clearly seen on the curves, the larger the capacity the more room there is for investment in Hydro-Electric installation.

3. The higher unit cost of the variable Head Turbines reduces naturally the comparative advantages of Hydro-Electric installation by some extent. The last factor (increased in our original equation) being constant, this reduction of advantage is the same for each size of plant, whatever the load factor.

4. The curves confirm the "immense" importance of the load factor ("Water Power" by J. W. Meares). The advantage of Hydro-Electric plant grows with the increase of load factor, but the curves becoming "flatter" for higher load factors indicate that more advantage is gained for larger installation.

5. The influence of load factor on installation of a given size can be deduced from the curves by interpollation of the space between the curves constructed for different load factors.

A curve constructed for a given size of installation would clearly show the influence of load factor, as in the example given below for an installation of 2000 kW. The influence is expressed by a curve, the equation being of the type

$$X = C + y f(y)$$

Where C is a Constant

f (y) a Function of y

The curve is "flatter" in the region of low load factors.

INFLUENCE OF LOAD FACTOR 2000kW PLANT
(CONSTANT HEAD TURBINE)

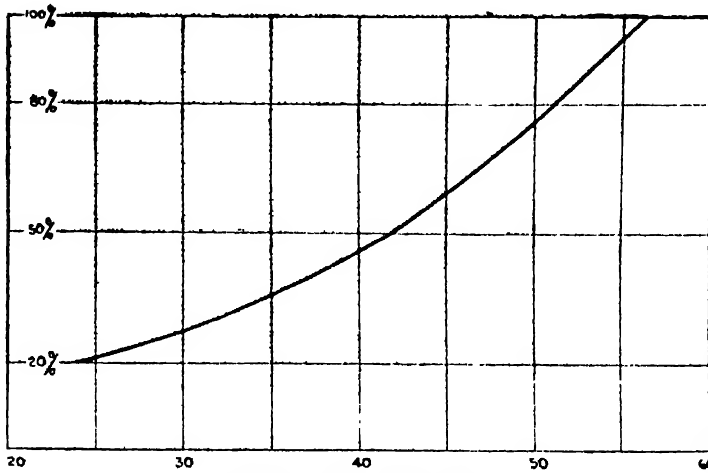


Fig. 2.

6. The influence of the cost of fuel follows a straight line law as shown in the diagram below (worked out for a 20000 kW plant on 100% load factor), the equation being of the type

$$X = C + C' y$$

Where C & C' are Constants.

INFLUENCE OF COST OF COAL
2000 kW PLANT (CONSTANT HEAD TURBINE)
100% LOAD FACTOR

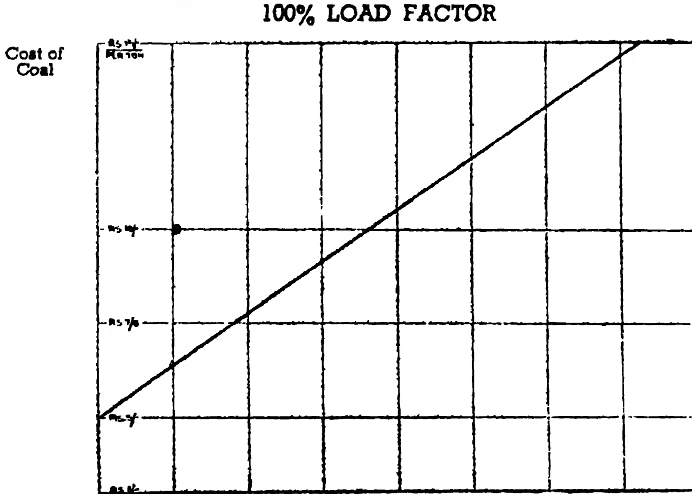


Fig. 3.

The curve shows the investment which may be justified in civil works for Hydro-Electric installation (and main transmission Line) increasing in slightly lesser degree than the cost of fuel, one factor only, the third (even if the most important) increasing proportionally in our original equation.

7. In conclusion, the striking contrast between the Thermal and Water generation should be mentioned, obtainable when some of the plants may be idle. Extra available units if sold by Hydro-Electric plant bring money without involving *any* expenditure while *every* unit sold from a thermal plant costs a definite sum in fuel. In this respect, paradoxical as it may seem, the lower is the load factor, the more "idle" extra units there are potentially available for sale and therefore the more comparative advantage may be gained by Hydro-Electric Plant.

ILLUSTRATION OF A TOWN SUPPLY

LOAD FACTOR DIAGRAM

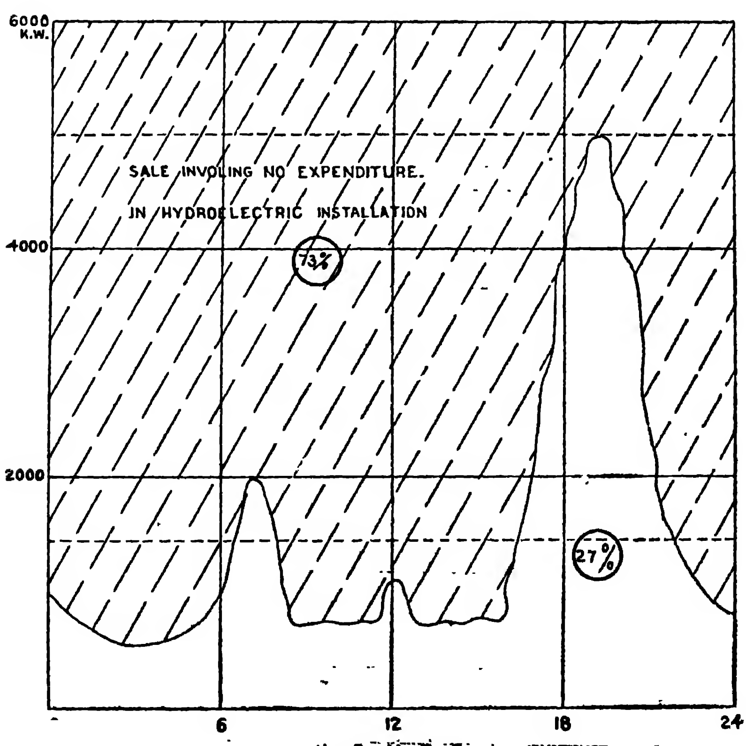


Fig. 4.

To illustrate this graphically two load factor diagrams (borrowed from "Water Power" by J.W. Meares) are shown in figs. 4 and 5 upon which the portions of sale which would involve no expenditure in Hydro-Electric installation are scored.

ILLUSTRATION OF A FACTORY

LOAD FACTOR DIAGRAM

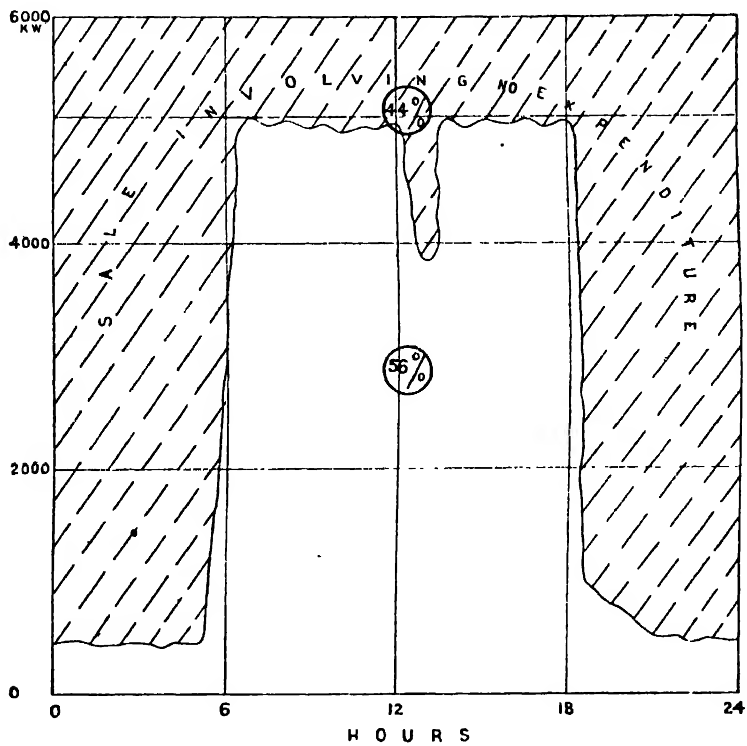


Fig. 5.

This quality may for instance be appreciated in the case of Hydro-Electric Station which is assisting a Thermal Plant to which it is linked.

In Indian conditions to this category should perhaps belong units which may be generated by the water otherwise escaping by overflow from storage reservoir in the years of plentiful rainfall, naturally within the capacity of Hydro-Electric Plant, dependant on the storage, the idea having been contributed by Sir William Stampe in his recommendations on Gwalior proposals.

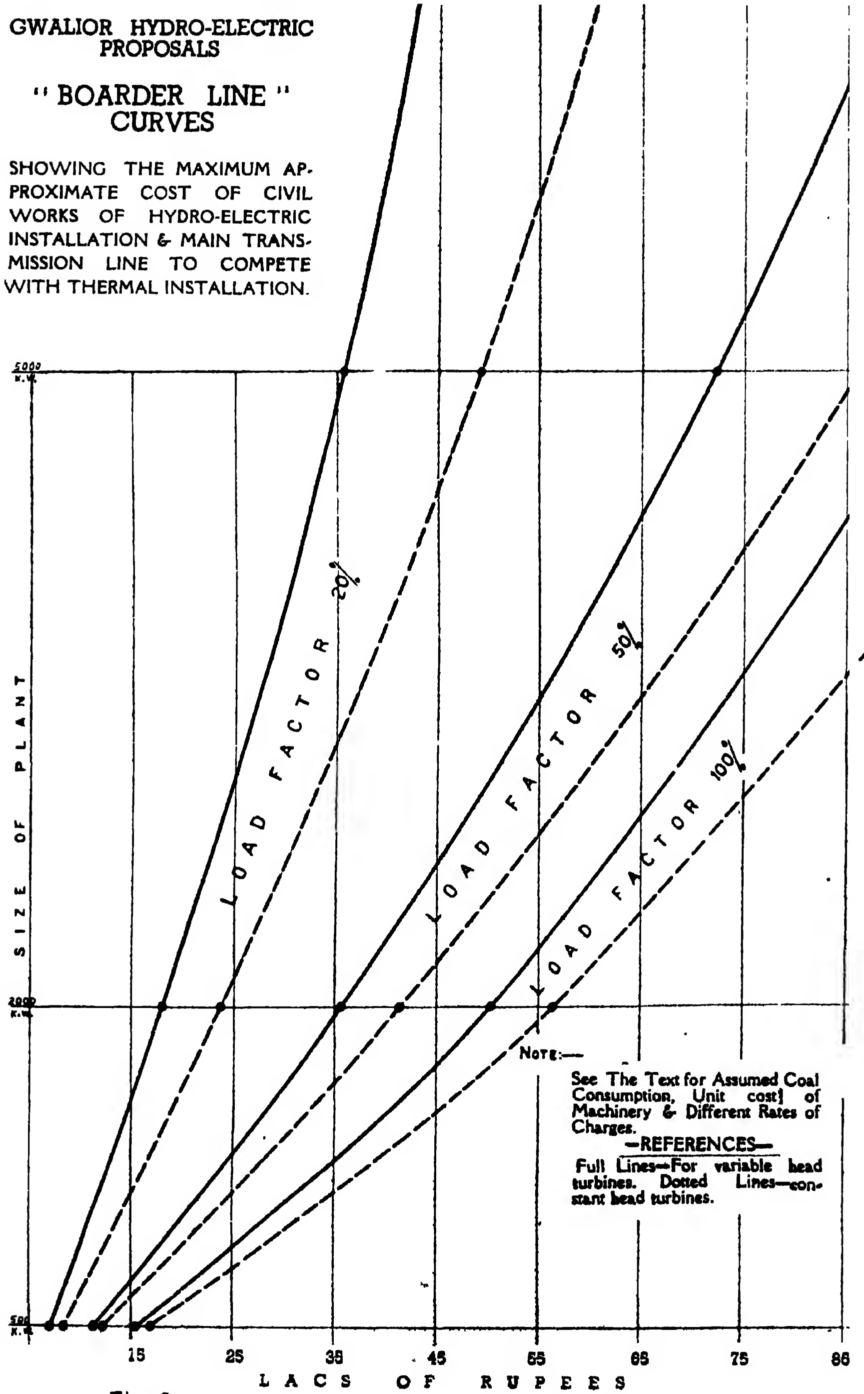

GWALIOR HYDRO-ELECTRIC PROPOSALS
" BOARDER LINE " CURVES
SHOWING THE MAXIMUM APPROXIMATE COST OF CIVIL WORKS OF HYDRO-ELECTRIC INSTALLATION & MAIN TRANSMISSION LINE TO COMPETE WITH THERMAL INSTALLATION.
5000 K.W.
2000 K.W.
500 K.W.
SIZE OF PLANT
LOAD FACTOR 20%
LOAD FACTOR 50%
LOAD FACTOR 100%
15
25
35
45
55
65
75
85
LACS OF RUPEES
NOTE:—
See The Text for Assumed Coal Consumption, Unit cost of Machinery & Different Rates of Charges.
—REFERENCES—
Full Lines—For variable head turbines. Dotted Lines—constant head turbines.

Fig. 6.

PAPERS MEETINGS

Bengal Centre

Air Conditioning of Hospital Operating Theatres[1]

Ideal Conditions Demanded by Hospital Operating Theatres and the Optimum Air Conditions.—Air conditioning, as applied to physiological needs of human beings, has been the subject of a great amount of research in America and other countries during the past few years, and it has been found to be a valuable adjunct in the treatment of various diseases. Among the important applications are those in the operating theatres, nurseries for premature infants, maternity and delivery rooms, and in the control of allergic disorders.

The widest application of air conditioning in hospitals is that in operating theatres. It has been discovered, for instance, that in addition to the normal requirements of air conditioning for comfort cooling, the presence of dangerously explosive anaesthetics such as, Ethyl Chloride, Ether, Ethelyne, etc., make it necessary for special precautions to be taken to avoid both unhealthy conditions in the room and the accidental explosion of these combustible mixtures. Explosion hazards in operating rooms have begun with the introduction of modern anaesthetic gases and anaesthesia apparatus. The most dangerous period is at the end of the operation when the patient's lungs are customarily washed out with oxygen with or without the addition of carbon dioxide. Even when this procedure is omitted, it is difficult in practice to avoid dilution of the anaesthetic gas with air during the normal course of breathing following the administration of anaesthesia. In either cases extraordinary precaution is necessary for the safety of the patient and operating personnel. The most important cause of accident is probably due to the formation of static sparks which may result from accumulation of frictional charges on the rubber surfaces of the anaesthesia apparatus, on woollen blankets, and on the bodies of the operators as they walk on floors, when the humidity is quite low. Since this results only when a very dry condition obtains, it is essential to limit the relative humidity between 50 to 60 per cent.

1. This paper presented by Mr. B B. Ghosh, B. E., Stud. I. E., Air Conditioning Engineer, Refrigerators (India) Ltd., Calcutta, before the Bengal Centre, won the Sir R. N. Mookerjee prize.

Again under the influence of anaesthesia, a patient is at a very low ebb. All anaesthetics, as a rule, are vasodilators, and produce dilation of the vessels in the skin and much sweating, particularly in the case of ether anaesthesia. The loss of body heat is increased considerably, while the general metabolism may be depressed. The organism loses ability to regulate its own temperature and becomes unusually sensitive to chilling and post-operative complications. It has therefore, become customary to defer major operations as much as possible until the passing away of heat waves in hospitals not equipped with cooling facilities. But there are exceptional cases, like acute appendicitis for instance which sometimes come with summer heat waves, and develop dangerously unless promptly operated upon. Aside from the possibility of post-operative heat stroke in warm and sultry weather, the surgeon is also concerned with the lowered recuperative power of the patients, and with his own discomfort as well as the discomfort of his team, which impairs the efficiency of the technic to the disadvantage of the patient. Complete air conditioning of operating theatres is therefore not only desirable but often necessary for reducing the risk of explosion of modern anaesthetic gases, and for the protection of the patient and operating personnel against excessive summer heat and winter cold.

So far as the comfort conditions necessary in the operating theatre are concerned, most surgeons and hospital authorities agree that 80° F. is the minimum desirable inside temperature, but as this temperature has been chosen under conditions where the normal temperature is in the range of 90° to 95° F., authorities are in general agreement that a definite temperature drop is the more satisfactory way of fixing the inside temperature and 10° to 15° F. has been fixed as the best temperature drop necessary for operating theatre conditions, *i.e.*, if under normal weather conditions, the theatre has a temperature of 95° F., the minimum temperature should not be lower than 80°F. This results in the patient not being subjected to shock upon entering the cooled room and tends to prevent his becoming too cold with detrimental effects.

Again a high air flow of at least 6 to 10 air changes per hour and preferably 100 per cent outside air in operating rooms is desirable for three reasons:

(a) to reduce the concentration of the anaesthetic to well below the physiologic threshold in the vicinity of the operating personnel. (vide Table—1)

(b) to remove excessive amounts of heat from the powerful surgical lights, solar heat, and from the bodies of the operatives, and

(c) to provide extra capacity for quickly preparing the room for emergency operations.

TABLE—1, EXPLOSIVE PROPFRTIES OF ANAESTHETICS

Anaesthetics	Limits of Inflammability per cent			
	Mixed with air		Mixed with oxygen	
	Lower	Upper	Lower	Upper
Ethylene	3·0	30	3·0	80
Ethyl Chloride	4·0	15	...	...
Ether	1·7	27	1·8	85
Chloroform	...	...	Not Inflammable	

From the foregoing statements, the basic requirements of an air conditioning installation for hospital operating theatres may be summarized as follows:

1. An installation for the operating room of a hospital must meet needs of both surgeon and patient.

2. Perspiration must be eliminated where possible, because tiny drops of perspiration containing bacteria may fall into an open wound.

3. Clouding of glasses during an operation hinders the surgeon in his work, and as his hands are never free to wipe them off, this must be done by an assistant. Atmospheric conditions in an operating room should eliminate the possibility of fogging spectacles.

4. Formation of static electricity must be prevented, as a static spark may cause an explosion of anaesthetic gases. It is essential that a high absolute humidity be maintained, irrespective of the relative humidity conditions.

5. Operating rooms must be aseptic, so it is important that a positive supply of clean, filtered air, free from dust, dirt and bacteria, be introduced into the room.

6. Drafts must be eliminated.

7. Because of the fact that anaesthetics form layers of gas close to the operating room floor, odour concentration in the room must be dispelled by air movement.

8. 100% outside air is necessary, as recirculated air would be laden with anaesthetic gases.

9. No equipment such as fans, motors, wiring, controls or other devices, that produce an electric spark shall be installed in the room.

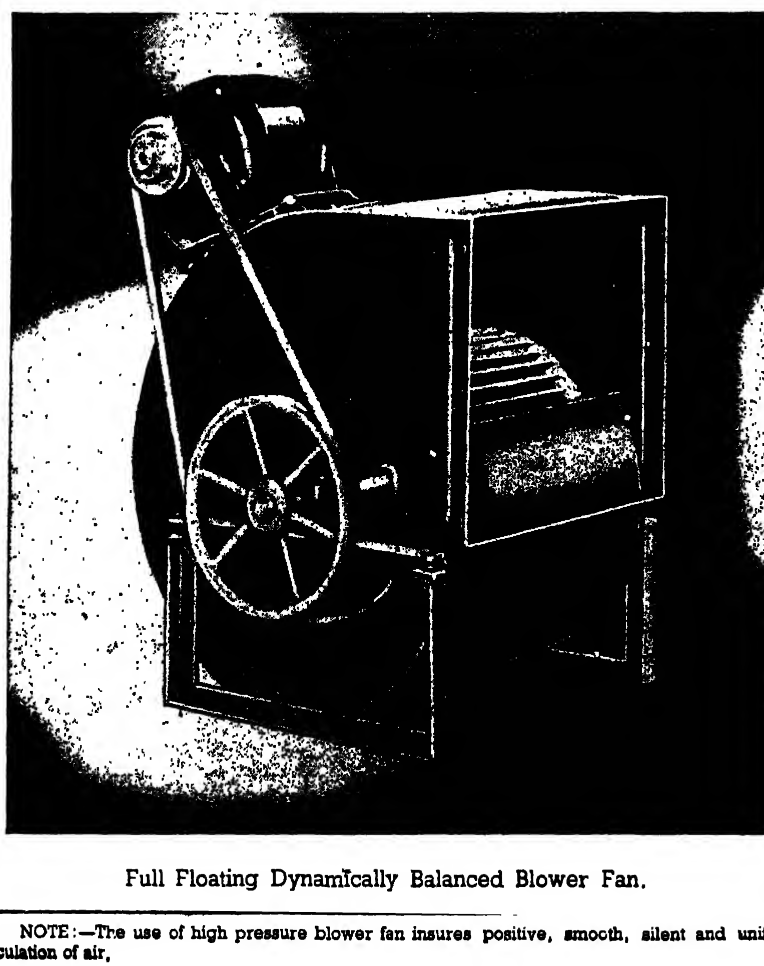
10. Although the comfortable air conditions for the operatives are not identical with those of the patient, a compromise should, however, be made; and a relative humidity of 50% to 60% with a temperature of 80 to 85° F. in warm weather and between 72 and 75° F. in cold weather have been found satisfactory.

11. Winter conditioning should have positive control of temperature and humidity irrespective of outside air conditions.

12. Summer air conditioning should have positive control of temperature and humidity, but the design dry bulb need not be so low as in many types of air conditioning installations.

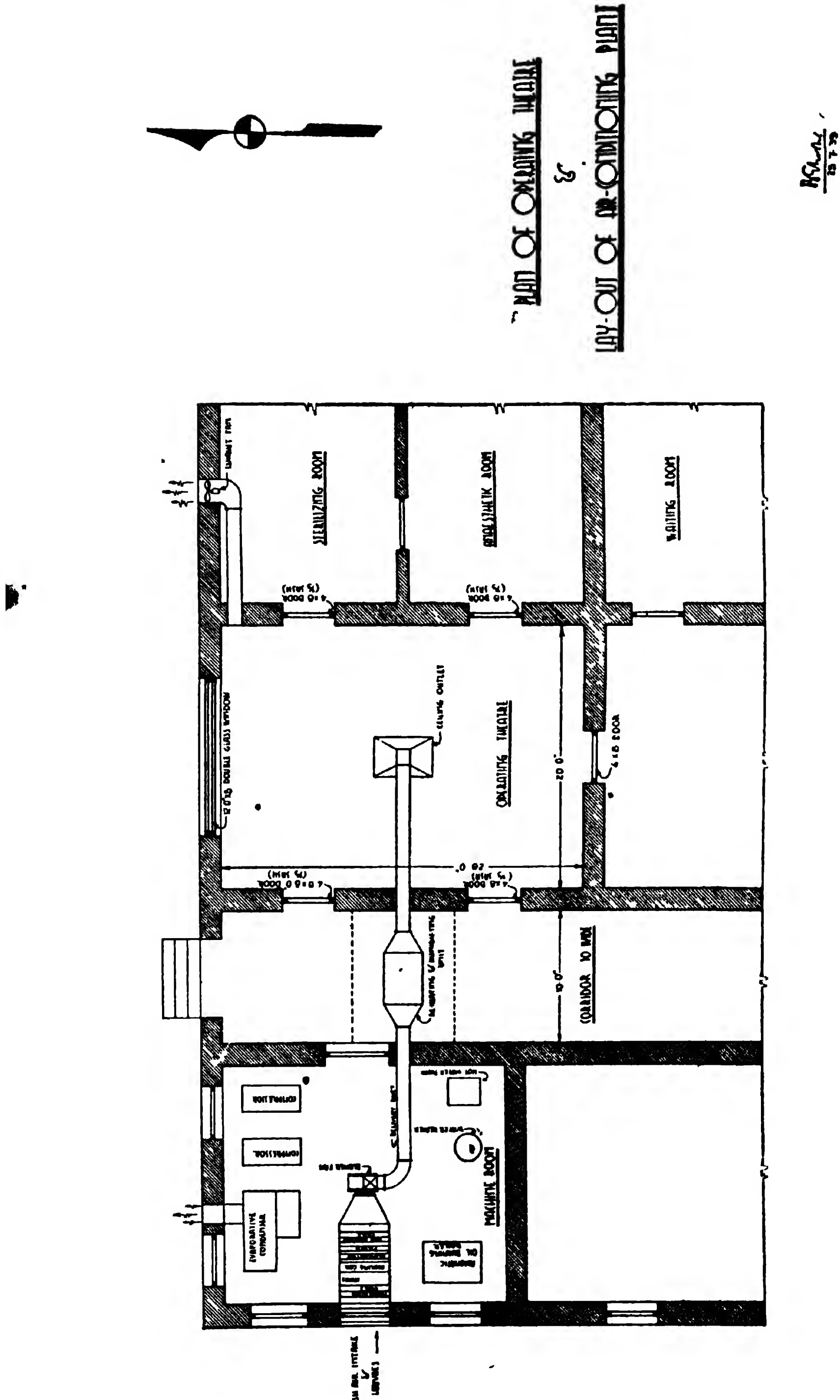
General Layout of Air Conditioning Equipment.—To meet the above requirements, an ideal air conditioning system for a typical hospital operating theatre based on the average summer and winter weather conditions prevailing in India, has been described below. The equipment will permit accurate and automatic control of the operating room, both as to temperature and relative humidity conditions. These conditions may be varied according to the desires of the operating surgeon by setting the thermostat and humidistat in the room.

Temperatures can be controlled within one degree above or below any setting and relative humidities within $\pm$ 2 per cent of any setting.



Full Floating Dynamically Balanced Blower Fan.

NOTE:—The use of high pressure blower fan insures positive, smooth, silent and uniform circulation of air.


PLAN OF OPERATING THEATRE
&
LAY-OUT OF AIR-CONDITIONING PLANT
STERILIZING ROOM
ANAESTHETIC ROOM
WAITING ROOM
OPERATING THEATRE
CORRIDOR 10 WIDE
MACHINE ROOM

Working to such close limits of temperature and humidity is a matter of control. The automatic controlling instruments are of the pneumatic type, which fulfills the requirements of the surgeons that no electric sparking device be installed in the operating rooms.

The air-handling system itself consists of a central air conditioning unit, located in the machine room; one auxiliary reheating and humidifying unit is located above a subroof over the corridor and serves the operating room. Supply ducts located in the same space connect the reheating unit with one diffuser type delivery ceiling outlet for uniform distribution of the conditioned air throughout the room. (*vide* lay-out drawings).

A motor-driven exhaust fan and a system of sheet metal duct and grilles draw air from the operating room *via* the sterilizing room, and discharges it to the outside.

The central air conditioning unit consists of a slow-speed, single inlet, single width, multi-blade, centrifugal blower fan having a capacity of discharging 1,500 cubic feet of air per minute and driven by a ¼ horse power motor; two sections of steam tempering and heating coils; high dispersion heat transfer rifled cooling coils; self-cleansing oil filters, and humidifying sprays.

The reheating and humidifying unit consists of a hot water reheating coil; a section of hair glass filter, and a humidifying spray. The filter serving as an eliminator of entrained moisture.

Functions of the Proposed System.—The air conditioning system herein described is designed to provide all the year round air conditioning comprising:

SUMMER OPERATION	Cooling, Dehumidifying, Filtering, Circulating, and Ventilating.
WINTER OPERATION	Heating, Humidifying, Filtering, Circulating, and Ventilating

For the purposes of our equipment let us fix the following design conditions:

Outdoors :

Maximum —100° F. dry bulb and 82° F. wet bulb.

Minimum — 30° F. dry bulb and 25° F. wet bulb.

Indoors :

Summer conditions—80° F. dry bulb, 55% relative humidity.

Winter condition—72 °F. dry bulb, 50% relative humidity.

Number of Occupants :—Six in all.

With these conditions as basis, we can proceed to calculate the cooling and heating loads in details, and from that select the equipment.

Cooling load computations and selection of Cooling and Dehumidifying Equipment for Summer Operation.—In order to economically air condition the room by reducing the heavy solar gain through the roof and also the cubic capacity of the room, we propose building a subroof of one inch thick insulating boards at a height of twelve feet from the floor. This will reduce the solar heat gain through the roof by more than 30 per cent and thus reduce the size and cost of the plant necessary for air conditioning the room.

In air conditioning problems the sources of the load that must be carried by the refrigerating equipment are as follows:

(a) Normal heat transfer and solar radiation through windows, doors, walls, partitions, floors and ceiling, etc.,

(b) Heat liberated by the occupants within the enclosure,

(c) Heat introduced by infiltration of outside air and controlled ventilation,

(d) Heat emitted by various mechanical or electrical appliances, etc.

The process of heat transfer through a built-up wall section is complicated in theory, but in practice it is simplified by dividing a wall into its component parts and considering the transmission through each part separately. Thus the average wall may be divided into external surfaces, homogeneous materials and interior air spaces if any. Practical heat transmission co-efficients derived from actual experiments under typical conditions will give the total heat transferred by radiation, conduction and convection through any of these component parts and if the selection and method of applying

these individual co-efficients is thoroughly understood it is usually a comparatively simple matter to calculate the over-all heat transmission co-efficient for any combination of materials.

As an example assume a wall with over-all co-efficient U. Then,

$$H=A.U(t_o-t) \quad \dots \quad \dots \quad \dots \quad (1)$$

Where,

H=B.Th.U. per hour transmitted through the material of the wall.

A=area in square feet of the wall.

(t_o-t) = temperature difference between outside and inside air.

In practice it is usually the over-all heat transmission co-efficient that is required. The simplest method of combining the co-efficients for the individual parts of the wall is to use the reciprocals of the co-efficients and treat them as resistance units. The total over-all resistance of a wall is equal numerically to the sum of the resistances of the various parts, and the reciprocal of the over-all resistance is likewise the over-all heat transmission co-efficient of the wall. For a wall built up of a single homogeneous material of conductivity k and x inches thick the over-all resistance,

$$1/U=1/f_i+x/k+1/f_o \quad \dots \quad \dots \quad \dots \quad (2)$$

where,

$1/U$=over-all resistance

$1/k$=internal resistivity

$1/f$=film or surface resistance (f_i is inside surface and f_o outside surface)

For a compound wall built up of three homogeneous materials having conductivities k_1, k_2 and k_3 and thicknesses x_1, x_2, and x_3 respectively, the total resistance,

$$1/U=1/f_i+x_1/k_1+x_2/k_2+x_3/k_3+1/f_o \quad \dots \quad (3)$$

For a wall with air space construction consisting of two homogeneous materials of thicknesses x_1 and x_2, and conductivities k_1 and k_2 respectively, separated to form an air space of conductance 'a', the over-all resistance,

$$1/U=1/f_i+x_1/k_1+1/a+x_2/k_2+1/f_o \quad \dots \quad (4)$$

Likewise any combination of homogeneous materials and air spaces can be put into the wall and the over-all resistance of the combination may be calculated by adding the resistances of the individual sections of the wall.

Now substituting the values of the conductivities of the various materials from Table 2 in the above formula, we can derive the co-efficients of transmission of heat for the wall, floor and ceiling, etc.

For example the co-efficient of heat transmission of the outside wall (18″ thick) works out to be

$$1/U = 1/f_i + x/k + 1/f_o$$
$$= 1/1{\cdot}3 + 18/5 + 1/4$$
$$\text{or } U = 0{\cdot}21$$

HEAT GAIN CALCULATIONS :

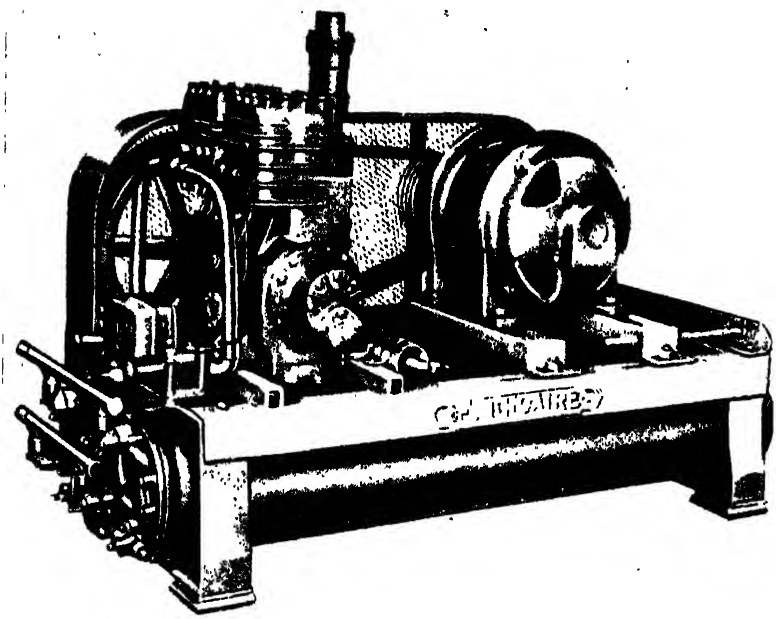
	B.Th.U. per hour
***Transmission Gain* :**	
Outside wall—144 sq. ft. ×0·21×20°	605
Glass—96 sq. ft. × 0·8 × 20°	1,536
Partition walls—752 sq. ft. × 0·21 × 18° (south, east and west)	2,844
Glass—42 sq. ft. × 0·8 × 18°	605
Doors—118 sft. × 0·69×18°	1,465
Ceiling—560 sq. ft. × 0·17 × (20° + 40°)	5,712
Floor—560 sq. ft. × 0·48 × 18°	4,838
***Infiltration* :**	
112 cfm. × 1·08 × 20°	2,419
***Internal heat* :**	
Occupancy—6 people × 225 B.Th.U. (*vide* Table 3) ...	1,350
Lights—500 watts × 3·4 B.Th.U.	1,700
Room sensible heat sub-total	23,074
Add safety factor @ 10%	2,307
(A) Room Sensible heat	25,381
***Room Latent Heat* :**	
Infiltration—112 cu. ft./m. × (135·9×83·2) grains per pound × 0 67	3,954
Occupancy—6 people × 236 B.Th..U.	1,416
Room Latent heat sub-total	5,370

TABLE 2. CONDUCTIVITIES OF BUILDING MATERIALS

Material	Conductivity (k)
Brick (low density)	5·00
Brick (high density)	9·20
Cement mortar	12·00
Concrete	8·30
Stone	12·50
Tile	10·00
Cork board (1″)	0·30
Celotex (1″)	0·33
Asbestos	2·70
Cement plaster	8·00
Air Spaces (over ¾″)	1·12
Surfaces :	
Still air f_i	1·30
15 mph f_o	4·00
Wood Teak (nominal thickness 1″)	1·45
Glass	1·25

TABLE 3. HEAT LOSS FROM HUMAN BODIES IN A TEMPERATURE RANGE FROM 60° to 90° F. DRY BULB.

Activity	Total heat dissipated, B. Th. U. per hour	Sensible heat dissipated, B. Th. U. per hour	Latent heat dissipated, B. Th. U. per hour
Average person seated at rest ...	384	225	195
Average person standing at rest ...	431	225	206
Office worker moderately active ...	490	225	265
Type writing rapidly ...	558	225	333
Bookbinder ...	626	225	401
Shoemaker ...	661	225	436
Carpenter ...	954	307	647
Walking 3 mph ...	1050	339	711



A Typical Air Conditioning Freon compressor[1].

	B.Th.U. per hour
Room latent heat sub-total ...	5,370
Add safety factor @ 10 % ...	537
(B) Room Latent heat	5,907

Room total heat = (A) + (B)

$= 25{,}381 + 5{,}907 = 31{,}288$

$$\text{Sensible heat factor} = \frac{\text{Room sensible heat}}{\text{Room total heat}}$$

$$= \frac{25{,}381}{31{,}288} = 0{\cdot}81$$

Therefore, Apparatus Dew Point = 58° (*vide* Table 4).

Dehumidifier rise = Room temperature—Apparatus Dew point

$= 80^\circ - 58^\circ = 22^\circ$

$$\text{Dehumidified air required} = \frac{\text{Room sensible heat}}{1{\cdot}80 \times \text{Dehumidifier rise}}$$

$$= \frac{25{,}381}{1{\cdot}08 \times 22}$$

$= 1068$

Say 1,100 cubic feet per minute.

1. The modern air conditioning condensing units use Freon (Dichloro-difluoro-methane), the odourless, non-inflammable, non-toxic, ideal refrigerant and insure safe operation.

Providing 100% outside air, we have,

Outside air heat :		B.Th.U. per hour
Sensible—1,100 cu. ft./m × 1·08 × 20	... ...	23,760
Latent— 1,100 cu. ft./m × 52·7 grs./lb. × 0·67	... ...	38,840
(C) Outside air heat	...	62,600

Adding (A) + (B) + (C), we have,

Grand total heat = 93,888 B.Th.U. per hour

Dividing this by 12,000 (B.Th U. obtainable per ton of melting ice)

we get, $\frac{93,888}{12,000} = 7{\cdot}8$

Say 8 tons of refrigeration of melting ice.

Table 4.

AIR CONDITIONS FOR OBTAINING APPARATUS DEWPOINT.

D.B.	W.B.	R.H.	Gr.-lb.	Sensible Heat Factor.	App. Dew Point °F.
80	69	58	89·1	0·68 0·64 0·62 0·60 0·58 0·57 0·56 0·54	58 56 54 52 50 47 44 41
80	68	55	83·2	0·81 0·77 0·72 0·69 0·62 0·60 0·59 0·58	58 56 54 52 50 47 44 41
80	67	51	78·5	0·85 0·77 0·72 0·69 0·66 0·64 0·62 0·61	58 56 54 52 50 47 44 41
80	66	48	73·0	0·96 0·85 0·79 0·74 0·71 0·68 0·66 0·64	58 56 54 52 50 47 44 41

Selection of Compressor and Coils.—An air conditioning unit which has a cooling or refrigerating capacity of 8 tons and with a direct expansion coil designed to give the desired performance with a ratio of 81 per cent sensible cooling with the balance dehumidification or latent cooling effect will handle the job. But in order to provide flexibility two compressors should be used instead of a single large one. The compressors will be controlled by a two-stage thermostatic switch. When started both the compressors will be in operation and as the room approaches the required temperature, one compressor will be automatically stopped and the other continue running until the required temperature is attained.

This will give considerable flexibility of control and during emergency operation, the two compressors will quickly bring the room temperature down to the required point after which one compressor will automatically hold it there and when the load increases due to weather conditions or otherwise, the second compressor will automatically cut in and handle the additional heat load still maintaining the room at the required temperature.

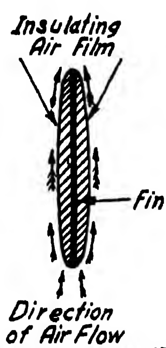
Furthermore, the dual installation gives added protection against complete breakdown and economises refrigeration cost.

An Evaporative Condenser having a total capacity of about 8 tons of refrigeration will be used. The use of this unit will reduce necessary water consumption to a small fraction of that required by regular water-cooled types of installation and increases the efficiency of the air conditioning unit.

The cooling coil will be of the latest High Dispersion heat transfer surface 'Rifled' type and capable of handling 1,100 cubic feet of air per minute.

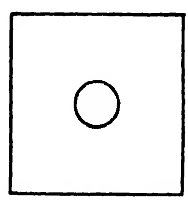
High dispersion surface was developed from an hypothesis based on the fact that a semi-stangnant air film is present along the flat finned surfaces of coils used in forced draft cooling. It is a common knowledge that if air is forced perpendicularly at a flat surface which is at a lower temperature than the air, this cooler flat surface will remove more heat from the air than would be removed were the air moving in a direction parallel to the plane of the flat surface. This phenomenon is caused by the fact that when the air is moving in a parallel direction there is a much slower moving film of air between the main air stream and the flat surface, such as the fins of a

finned coil (*vide* Figure 1). Heat from the faster moving air stream must pass through this more slowly moving air stream before it can reach the finned cooling surface and, inasmuch as air is a poor conductor of heat, this slow moving, almost stagnant air film materially slows down the rate of heat transfer. However, this insulating air film is not present at the edges of the fins which are directly exposed to the air stream. Obviously, if this insulating air film can be broken up by the elimination of relatively large areas of flat surfaces whose planes are parallel to the direction of air flow, the rate of heat transfer is



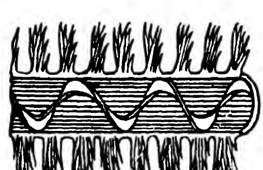
DEMONSTRATING THE INSULATING EFFECT OF AN AIR FILM ON FIN

Fig. 1



ORDINARY SQUARE FINS LIKE THIS

Fig. 2



HIGH DISPERSION SURFACE COIL SHOWING INTERIOR RIFLING WITHIN TUBING

Fig. 3

going to be materially increased. High Dispersion Heat Transfer surface successfully eliminates the parallel flat areas of the fins and substitutes in their place, thousands of slender spines with thousands of heat entering edges. Rifling as

indicated in figure-3, is a brass strip that is inserted in the tubing, stretched to greater length than the tubing itself, and then allowed to expand against the inner tubing wall. Thus, a spiral motion is imparted to the refrigerant as it passes through the tubing, causing it to wash the entire inner wall instead of just trickling along the bottom of the tube, as would be the case were the tubing not rifled. Thus, heat is transferred to the refrigerant at every point on the tubing wall instead of primarily at the bottom portion of the tubing. Rifling acts as interior finning, actually extending the inner wall of the tubing into the refrigerant.

Performance.—In the Summer season the air will be first cooled to approximately 56° to 58° F. and 100 per cent relative humidity by the cooling coil ; filtered by the oil filters ; and delivered to the reheating and humidifying unit where it will be finally raised to the temperature and humidity desired.

In order that the reader may get an idea of the refrigerating cycle, let us consider the illustration below which shows that part of the equipment which has to do with the Refrigerating Cycle.

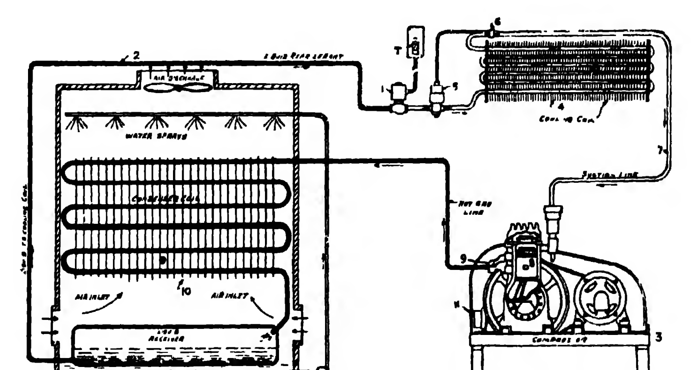


DIAGRAM OF REFRIGERATING CYCLE

25-7-39.

If the thermostat (T) is calling for more cooling in the room, an electrical contact is made inside it. This electric contact opens and electric valve known as a solenoid valve (1) which permits liquid Freon refrigerant to flow through the copper tube (2) known as the liquid line, from the condensing unit (3) to the cooling coil (4) located in the air conditioner. This liquid Freon is under a pressure of approximately 120 pounds. Before entering the cooling coil, the Freon also passes through what is called a thermostatic expansion valve (5) and in so doing, the pressure on the Freon is released. The function of a thermostatic expansion valve is to regulate the amount of liquid refrigerant that enters the cooling coil. All refrigerants have their own pressure-temperature relationships. That is, they boil, or begin to vaporize, at temperature corresponding to the pressure conditions existing. When the pressure of the liquid refrigerant is reduced, as in going through an expansion valve, it will immediately start to vaporize at the temperature corresponding to the reduced pressure. This vaporization of the liquid refrigerant requires the addition of heat, just as heat is required to generate steam from water. In the case of a refrigerant confined inside a coil, the heat required for vaporizing the liquid comes from the surrounding air which is at a higher temperature. The heat transfer is from air to coil, to refrigerant. One of the characteristics of this refrigerating cycle is that when this pressure is released and the Freon passes into the coil, the Freon immediately drops to a temperature between 30° F. to 50° F. and to a pressure between 28 lbs. and 47 lbs. depending on the characteristics of the particular installation. This change of state of the liquid Freon to a gas is accomplished through a rapid absorption of heat from cooling coil over which the air is being drawn by the fan.

As the coil absorbs heat from the air, it reduces the air temperature to below the Dew Point temperature, whereupon the moisture in the air is condensed out by the cold coils. This moisture collects on the cold coils, drips into the drip pan and is then removed through the drain line. The relative amounts of heat and humidity in the air as extracted by the conditioner can be increased or decreased by varying the amount of air or changing the temperature of the coils.

Since the heat transferred from coil to refrigerant during the vaporizing process accomplishes the desired refrigeration, economy demands that the vaporization takes place, as much as

possible, throughout the coil in order to utilize the entire coil surface. When the liquid becomes completely evaporated, any further addition of heat is in the form of superheat and is reflected in a rise in temperature of the vapour, with a small absorption of heat, whereas the liquid refrigerant in vaporizing absorbs considerable heat at no rise in temperature. This superheat provides the principal means of controlling the action of the thermostatic valve. The valve proper is located at the inlet to the coil and has its thermostatic bulb (6) attached near the suction outlet of the coil. For most applications, it is desirable to control the admission of liquid refrigerant so that by the time it reaches the bulb location it is completely vaporized and has taken on about 10° of superheat. The Freon, after passing through the cooling coil and absorbing heat from the air, is now a gas and passes back to the condensing unit througn the copper tube (7) known as the suction line, with a temperature and pressure slightly higher than when passing through the cooling coil. This gaseous Freon is drawn into the compressor (8) by the action of the piston in dropping to the bottom of the cylinder. Then, as the piston rises again, this gaseous Freon is compressed until, at the top of the Piston stroke, it passes through a valve at the top of the cylinder and into the copper tube or 'Hot gas line' (9). At this point the Freon is still a gas, but the temperature is greatly increased and the pressure is about 120 lbs. This gas then passes to a finned coil in the Evaporative Condenser., A Water spray keeps the outer surface of this coil covered with a film of water while a fan circulates a stream of outside air over this finned coil. As the air passes over the condenser, it naturally removes heat from the compressed refrigerant. This cooling is further greatly accelerated by the evaporation of the moisture from the coil surfaces, so that the refrigerant may again condense and collect in the liquid receiver. It then passes to the cooling coil in the air conditioning unit to provide further cooling in the usual way. Thus, instead of there being a constant supply of runnnig water necessary, as with an ordinary water-cooled condensing unit, the evaporative condenser uses the water over and over—only about 5 per cent being evaporated into the air and wasted. An evaporative condenser therefore saves as much as 95 per cent of the water consumption of water-cooled condensing unit.

Now when the temperature (dry Bulb) of the room reaches the thermostat setting, the contact in this device opens and breaks the electrical circuit to the solenoid valve in the air

conditioner, allowing this valve to close and stop the flow of liquid Freon to the coil. This action will cause the pressure in the suction line to be reduced as the compressor continues to operate, until a pressure control in the compressor stops the compressor motor before the pressure gets too low.

***Heating Load Computations and Selection of Heating and Humidifying Equipment for Winter Operation*: *Heat loss calculations*.**—Without going into details, the heat loss for the winter operation may be approximately calculated from the heat gain calculations foı the summer operation. We find the 'Room sensible heat' during the summer, for a 20° F. differential between the room and outside temperature is 25,381 B.Th.U. per hour, or 1,269 B.Th.U. per hour per degree differential between the room and outside air. So during the winter operation, when the differential between the room and outside air temperatures is 42°, the heat loss may be roughly taken as 1,269 × 42 or 53,300 B.Th.U. per hour.

Let us then assume the same quantity of 1,100 cubic feet of outside air to be circulated in this case and check whether the temperature of air leaving the outlets is within the working limit which is about 115° F.

$$\text{Now, } H = C_p \times M\ (t_y - t) \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where,

H = heat loss of space to be conditioned, B.Th.Us. per hour.
C_p = specific heat at constant pressure of dry air
M = weight of air passing
t_y = outlet temperature, degrees Fahrenheit.
t = inside temperature, degrees Fahrenheit.

From (1) we have,

$$t_y = \frac{H}{C_p \times M} + t$$

$$= \frac{H}{C_p \times d \times Q} + t \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where,

d = density of air
Q = volume of air introduced, cubic feet per hour.
Substituting the values of C_p and d in (2) we have,

$$t_y = \frac{55 \cdot 2\,H}{Q} + t \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Substituting the values in the above equation, we have

$$t_y = \frac{55 \cdot 2 \times 53{,}300}{1100 \times 60} + 72$$

$$= 116°$$

As the outlet temperature is rather on the high side, we would circulate 1,500 cubic feet of air per minute during the heating operation.

In the installation we contemplate using of a tempering coil, humidifying sprays of water, preheating coil and a reheater.

When the inside temperature is 72° F., 50 per cent relative humidity corresponds to a Dew Point temperature of 52° F.

Let us assume the efficiency of the humidifying sprays to be 85 per cent.

It will, therefore, be necessary to heat the outside air drawn into the apparatus by means of the tempering coils to such a temperature that the air in passing through the water sprays will become partially saturated (adiabatically) having a moisture content per pound of air equal to saturated air at 52° F.

If the incoming air is warmed to 90° F. its wet bulb temperature will increase to 56° F. and if the humidifying efficiency of the sprays were 100 per cent, the air would have become adiabatically saturated at this entering wet bulb temperature of 56°F. or a temperature drop of (90—56)=34° F. would have resulted. The efficiency of the sprays is, however, only 85 per cent, so that the actual temperature drop will be 0·85×34 or 29° and the conditions of the air after it leaves the sprays will be (90—29) or 61° F. dry bulb temperature and 72 per cent relative humidity.

The heat to be supplied by the tempering coils is equal to :

$$\left.\begin{aligned} & 0{\cdot}24\ (90-30)\ M \\ &= 0{\cdot}24 \times 60 \times 1{,}500 \times 60 \times 0{\cdot}08 \\ &= \mathbf{1{,}03{,}680}\ \text{B.Th.U. per hour.} \end{aligned}\right. \quad \left\{\begin{array}{l}\text{Where, M is the}\\ \text{weight of air}\\ \text{passing}\end{array}\right.$$

We will then heat this air to about 100° F. by the preheating coils and finally reheat and humidify to the desired conditions by the reheat Unit.

The heat to be supplied by the preheating coils is equal to:

$$\begin{aligned} & 0{\cdot}24\ (100-61)\ M \\ &= 0{\cdot}24 \times 39 \times 1{,}500 \times 60 \times 0{\cdot}08 \\ &= \mathbf{67{,}392}\ \text{B.Th.U. per hour.} \end{aligned}$$

The reheating and humidifying unit should have a capacity of reheating the air by about 10° F. thus providing a wide range of flexibility.

The reheating coils will be of hot water type and the heat to be supplied the reheating coils is equal to:

$$0{\cdot}24 \times 10^\circ \times 1{,}500 \times 60 \times 0{\cdot}08$$
$$= \mathbf{17{,}280} \text{ B.Th.U. per hour.}$$

Selection of Boiler and Steam Heating Coils.—Automatic fuel burning boiler co-ordinating the oil burners or gas burners with boilers of special design and construction for application on steam heating systems are now available in the market, and once the total load is computed, the type and size of the boiler may be selected from the manufacturer's catalogue and data. In selecting the boiler sufficient allowance should be made for the heat loss in pipings.

Low pressure steam heating coils may be designed on the basis of an average emission of 240 B.Th.U. per square foot of radiation per hour and high temperature hot water heating coils on the basis of an average emission of 200 B.Th.U. per square foot of radiation per hour.

The tempering coils will consist of two sections of high dispersion low pressure steam coils having a total heating surface of about 500 square feet and the preheating coils will have a total heating surface of about 300 square feet.

Selection of Reheating Unit.—In the case of a forced circulation direct return hot water heating system, the necessary radiator heating coil and water heating appliances may be easily selected once we know the amount of heat to be supplied. The most important thing is the selection of suitable pump and the requisite size of the hot water circulating pipings, and the following method will be found convenient for the purpose.

Referring to the layout drawing let us assume that the supply line consists of 50 feet of iron pipe, 1 heater; 1 radiator; 1 radiator valve; 1 stop cock; 6 ells and 3 tees; and the return line consists of 40 feet of iron pipe; 3 ells and 1 tee.

The friction in the various fittings should then be expressed in terms of the friction in 90° elbow from the values given in Table 5. The supply line then consists of 50 feet of pipe and 26·5 elbow equivalents (assuming each tee is equivalent to 4 ells) and the return line consists of 40 feet of pipe and 7 elbow equivalents.

The friction head in one elbow is approximately equal to the friction produced by the same sized pipe 25 feet in length. Assume that the pipe size for this system is ¾ inch. The equivalent length of the supply line will then be 50 feet plus 42 feet or 92 feet and the equivalent length of the return line will be 52 feet.

Having determined the equivalent length of the lines, the next step is to assume the rate at which the water is to be circulated in the system. The water may flow through the system so that it will cool down to any reasonable number of degrees. For the most economical average system a 20°F. drop is a satisfactory rate. One gallon of water per minute with a density of 7·99 at 215°F. will deliver approximately 9,600 B.Th.U. per hour with a 20°F. drop. In our case, the total radiation load is 17,280 B.Th.U. or say 18,000 B.Th.U. per hour, therefore, the pump must deliver $\frac{18{,}000}{9{,}600} = 1{\cdot}8$ or say 2 gallons of water per minute or 1200 lbs. per hour.

Knowing that the rate of flow is 2 gpm, the next step is to determine from the characteristics of available pumps, which one will produce satisfactory velocity in the system.

Assume that a circulating pump which will provide a pressure head of 3 feet is selected.

TABLE 5. IRON ELBOW EQUIVALENTS.

1 90-deg. elbow	1·0
1 45-deg. elbow	0·7
1 90-deg. long turn elbow	0·5
1 open return bend	1·0
1 open gate valve	0·5
1 glove valve	12·0
1 angle radiator valve	2·0
1 boiler or heater	3·0
1 radiator	3·0

Values in elbow equivalents for the most common percentages of water diverted in a 1 × 1 × 1 in. tee are as follows:

25 per cent	16·0
33 per cent	9·0
50 per cent	4·0
100 per cent	1·8

From Table 6, which indicates the total equivalent lengths for pressure heads from 2 to 6 feet we have, with a circulator having 3 feet pressure head and a system with a total equivalent length of 144 feet, the piping system is to be designed on a basis of 240 milli-inch of friction loss per foot of pipe.

Now referring to 240 milli-inch column of Table 6, ¾ inch pipe is shown to be the necessary size, ½ inch being too small.

The reheating coil will have a total heat emission surface of about 100 square feet, and the water heater supplying high temperature hot water (about 215° F.) to this coil will have a capacity of about 5,000 watts.

TABLE 6. CAPACITIES FOR BLACK IRON PIPE*

A = Carrying capacities, thousand B.Th.U. per hour.
B = Velocity in inches per second.

Head Loss Ft.	Milli-inch Friction Loss per Foot of Pipe. 480	360	300	240	180	160	144	120
	Equivalent length of pipe in feet. (longest circuit).							
2	50	66	80	100	133	150	167	200
2½	62	84	100	125	167	188	208	250
3	75	100	120	150	200	225	250	300
3½	87	117	140	175	233	263	291	350
4	100	133	160	200	266	300	333	400
4½	112	149	180	225	300	338	374	450
5	125	167	200	250	333	375	416	500
5½	137	183	220	275	366	413	457	550
6	150	200	240	300	400	450	500	·600
Nominal Pipe Size In.	Capacities of pipes, thousand B.Th.U. per hour with a 20° F. drop.							
½ A	16	14	13	11	10	9	9	8
½ B	22	19	17	15	13	12	11	10
¾ A	35	30	27	24	21	19	18	17
¾ B	25	23	21	18	16	15	14	13
1 A	70	60	54	48	41	39	36	33
1 B	32	27	25	22	19	18	17	15

* The above table has been developed by the American Society of Heating and Ventilating Engineers.

Performance.—In the winter season the air will first be tempered to about 90° F. by the tempering coils; in passing through the humidifying sprays the air will be cooled to about 61° F. and 72 per cent relative humidity; filtered by the oil filters; heated to about 100°F. dry bulb by the preheating coils; and delivered to the reheating and humidifying unit where the air will be raised to the temperature and humidity desired.

Automatic Control System.—Temperature and humidity are automatically controlled through each step of the air conditioning process. In the winter season the temperature of the air leaving the tempering coils will be controlled by a duct-type thermostat located in the spray chamber. One bank of tempering coils is to be hand-controlled.

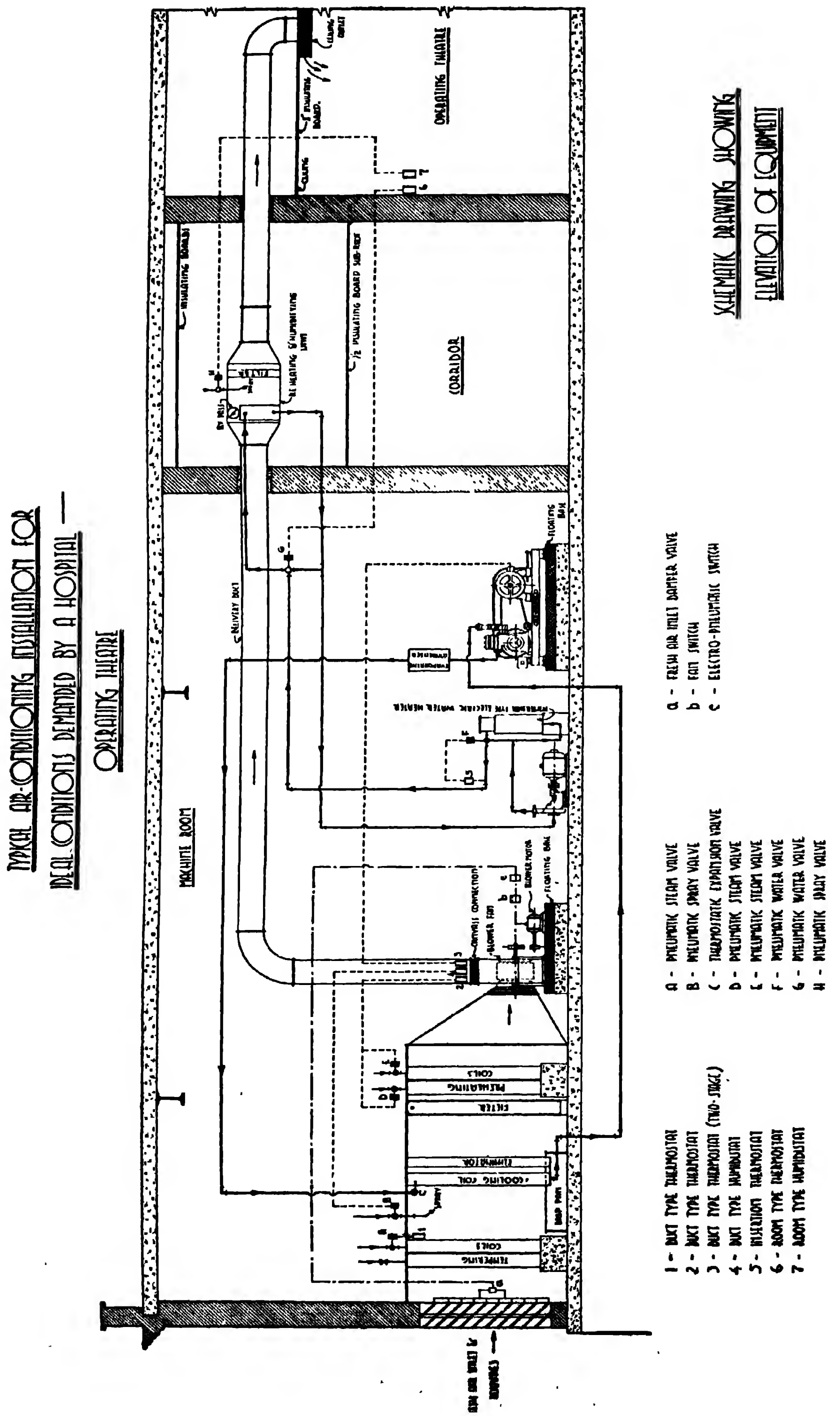
A second duct thermostat and a humidistat located in the blower discharge control the preheating coils. A room-type thermostat operates its by-pass valve to control the temperature of air from the reheat unit. A humidistat operates its water valve to control the humidifying spray in the reheat unit.

Steam for the tempering and heating coils of the central conditioner unit will be supplied from an oil burning boiler. The boiler is furnished with a low water cut-off for the steam heating system. Oil burner and all operating and safety controls are mounted inside the doors at the front of the cabinet where they are readily accessible, yet are out of the high temperature zone.

Hot water for the reheating coil is pumped by a motor-driven centrifugal pump through an immersion type electric-grid water heater and through supply and recirculating mains in a closed circuit.

The temperature of the water at the discharge of the heater will be automatically controlled by an immersion-type thermostat.

The two refrigerating compressors are automatically controlled by a two-stage duct type thermostat, each stage of which operates the solenoid valve installed in the refrigerant line of its respective compressor and causes the suction pressure to drop to a predetermined point when the low pressure control on the compressor trips and stops the compressor motor through the starter. Combined with this control is a safety control (the high-low pressure control)


TYPICAL AIR-CONDITIONING INSTALLATION FOR
IDEAL CONDITIONS DEMANDED BY A HOSPITAL —
OPERATING THEATRE
SCHEMATIC DRAWING SHOWING
ELEVATION OF EQUIPMENT
OPERATING THEATRE
CORRIDOR
MACHINE ROOM
CEILING OUTLET
INSULATING BOARD
INSULATING BOARDS
DELIVERY DUCT
BLOWER FAN
BLOWER MOTOR
FLOATING BASE
FILTER
PREHEATING COILS
COOLING COIL
ELIMINATOR
TEMPERING COILS
DRIP PAN
1 - DUCT TYPE THERMOSTAT
2 - DUCT TYPE THERMOSTAT
3 - DUCT TYPE THERMOSTAT (TWO-STAGE)
4 - DUCT TYPE HUMIDSTAT
5 - INSERTION THERMOSTAT
6 - ROOM TYPE THERMOSTAT
7 - ROOM TYPE HUMIDSTAT
A - PNEUMATIC STEAM VALVE
B - PNEUMATIC SPRAY VALVE
C - THERMOSTATIC EXPANSION VALVE
D - PNEUMATIC STEAM VALVE
E - PNEUMATIC STEAM VALVE
F - PNEUMATIC WATER VALVE
G - PNEUMATIC WATER VALVE
H - PNEUMATIC SPRAY VALVE
a - FRESH AIR INLET DAMPER VALVE
b - FAN SWITCH
c - ELECTRO-PNEUMATIC SWITCH

whose function is to shut off the condensing unit at any time if the pressure, or load on the system rises beyond a safe point.

Conclusion.—Aviation and wireless have annihilated time and space and they stand as great achievements to the credit of engineers as scientists to the civilization of the modern world. But air-conditioning is by far the greatest contribution of engineers to the amenities of our civilization, meeting, as it does, the most vital needs of human beings by providing health and comfort. It is no longer necessary to undergo the gruelling heat of the tropical plains during the summer and dry parched feeling during the winter when the nose, throat and lips get dried-up with consequent uncomfortable feeling. Air conditioning does away with the vagaries in changes of seasons and the people can now enjoy a perfect spring time all the year round with the help of 'manufactured weather' or 'made-to-order-breezes'. Ever since the rapid rise in popularity of the radio number of years ago, no highly technical engineering subject has held such public interest as air-conditioning, and the degree of progress achieved in this branch of engineering may well be judged from one of the most unusual air-conditioning ventures ever undertaken in the attempt made to duplicate actual Florida weather conditions in the Florida National Exhibit at the New York World's Fair. Not only was the air held at the mean temperature and humidity found in Florida, but the fragrant odour of Florida orange blossoms was added.

India is, however, far backward in taking up this new amenity to comfort and health and it is for the general interest of both the businessmen and the public in particular that they should extend the most suitable opportunities to the engineers for pioneering new ventures in this line.

Bombay Centre

My Experiences in Structural Steel[1]

Mr. P. E. Golvala in the Chair.

Mr. C. H. Shah traced the history of the developments of structural steel since Bessemer's invention in 1856 and showed how the introduction of Electric Arc Welding had made it

1. A lecture given by Mr. C. H. Shah at a General Meeting held on the 14th January 1941. Attendance 40.

possible to use structural steel in any form. He then pointed out how a structural engineer required knowledge of civil engineering as well as mechanical engineering. He further emphasized the necessity of shop and field experience, for a really successful design in structural steel. The scope for the use of structural steel was a very wide one and it included residential and industrial buildings, aeroplane hangars, cinema theatres and public halls, etc. The production of high tension steel had made it possible to have large opening.

The lecturer then showed by means of sketches the importance of the use of stiffeners and bracings and deprecated the tendency of short sighted clients who urge on their contractors to economise in these matters. The lecturer then very clearly illustrated how unreasonable insistence on obsolete bye-laws had been the cause of wasteful designs and he emphasized the necessity of taking advantage of the properties of continuous beams. He also expressed his views that in finding the strength of steel columns having a concrete core the strength of both the steel and the concrete should be taken into account. He then illustrated the adaptability of structural steel in cinema theatres and studios and illustrated how structural steel was admirably suited for future repairs or alterations. This was a great merit of structural steel as against reinforced concrete. The lecturer concluded by making a reference to the subject of structural welding.

Mr. E. A. Nadirshah expressed the view that clients should not be allowed to have their say in matters like stiffeners and bracings.

Mr. K. T. Divecha did not agree with the lecturer with regard to the use of bracings. He also showed how stresses due to vibrations were important in the design of cantilevers.

Mr. S. B. Joshi enquired if a welded joint was always as strong as the principal parts. He further added that reinforced concrete was only used where the cost of structural steel was prohibitive, and expressed the opinion that in the case of structural steel columns with concrete core, the strength of both the concrete and the steel could be taken into account only if the steel stress was limited to say 13,500 lbs. per sq. inch which is the prevailing practice.

Cinema Studios and their Equipments[2]

Mr. P. E. Golvala in the Chair.

Mr. K. T. Divecha in opening the lecture said that an engineer or an architect who was called upon to design the lay-out and buildings for a cinema studio must have detailed knowledge of the working of a modern studio in order to design the lay-out and the buildings. The cinema industry was a modern one, about 30 years old. In the days of silent pictures the making of films was very simple and they were almost entirely made in India with the aid of day light. What was required was a large open space about 50'×100' with poles on both sides and wires stretched across these poles, which allowed curtains to be put in for controlling the day light. With the introduction of sound, the making of the films became more difficult. The sound pictures must not only be so recorded as to exclude all unwanted sound but the recorded sound must also be without any echoes, reverberations and other sound disturbances. These pictures moreover were made with artificial controlled lights. The process of developing, printing, etc., had also considerably advanced during the recent years and required a more up-to-date laboratory. The cost of production had also gone up considerably and therefore efficiency in handling of men and materials had to be thought of while designing a studio. The coloured and television films were likely to be introduced in future and would create their own problems in the design and lay-out of a studio.

Continuing Mr. Divecha said that the working of a cinema studio was a complicated business. It started with obtaining a suitable story, writing of scenario, selecting artists to play the roles, making settings, shooting (which meant photographing and recording sound), developing the film, synchronizing, *i.e.* mixing the sound and photography, cutting, editing, polishing, printing positive copy, inspection by projection and preparing copies for release. All these required considerable knowledge of the industry and ability in selection of story, staff and controlling the production. A modern studio requires a large area of land. It should be about 25,000 sq. yds., but a plot of 25 acres was more desirable. In addition to the usual requirements for building sites, the site should possess an easy access, should be away from sources of noise and should have adequate supply of portable weather, drainage facilities

2. A lecture given by Mr. K. T. Divecha M.I.E. on the 28th January 1941 Attendance 47.

and cheap power supply. The buildings which were usually required was one big block of building which would accommodate administrative offices; dressing rooms ; wardrobe and tailoring departments; make-up room ; rooms for rehearsals ; library ; publicity department and a canteen. The other buildings were sound stage, which was the name given to the building in which settings were erected and shootings took place ; workshops ; sound recording room ; stores for raw materials ; film storage rooms ; camera rooms ; godowns for lights; property rooms; library; a projection room and garages. Besides these a power house and a well laid out garden were a necessity. The most important buildings were the sound stage and the laboratory, which were dealt with in details.

In explaining the details Mr. Divecha said that the lay-out of various buildings was very important. The positions of the buildings should be so arranged as to allow for convenient circulation of traffic of men and materials ; raw materials coming at one end and passing through workshops go to the sound stage and from thence to the property rooms to be stored for future use. The workshop should, however, be as far away as possible from the sound stages, because the modern power machinery employed in the workshops create considerable noise and would, if these were near sound stage, require more expensive sound-proofing of the stage. The sound stage was usually a large godown from about 50′ to 80′ × 100′ to 300′ in floor area with a height varying from 30′ to 40′. It should have thick masonry walls to exclude the outside noise. The interior of the walls should be treated with sound absorbing materials, such as Heraklith or coir padding to avoid echoes and reverberations. The roof must be made not only sound-proof but should be acoustically treated. The doors should be sound-proof. The ventilation of a sound stage was very important, the usual methods being forcing air in at one end and exhausting at the other end. Machinery and ducts should be so designed as to eliminate any sound coming from it (this was illustrated by drawings and explained in details). Air-conditioning would be the best method, but was prohibitive in cost. Electric wiring was required to be very liberally supplied, as quite a large number of lights, sometimes consuming about 200 kW at a time, were required in a single sound stage. Plug points should be so arranged as to cause minimum of nuisance from the cable which usually fell on the floor. Other facilities like galleries on the sides, running pulley blocks on the top, tanks in floors, revolving platforms in floors and such other things may be thought of

and provided at a small cost in the beginning. He was of opinion that it was preferable to have at least two sound stages in any studio ; when the work of erecting settings was being done in a stage, no shootings could be taken. Therefore while one sound stage was actually in use, settings could be erected in the other. The other important building was the laboratory, which should have dark rooms for the development of films. This should preferably be provided with light traps (which were explained by drawings and sketches) as they were most convenient. The floors and walls should be polished so that dust would not settle on them, as dust was a great nuisance for films, which would be exposed on the floor. The rooms where day light was permitted were best built with glass panes in the walls, instead of ordinary windows. The arrangements of the laboratory was explained at length. The projection room was required not only for viewing the pictures but also carrying out some work known as dubbing, which meant introducing sound on silent pictures and running commentary on news reels, etc. This was done by means of providing sound-proof booths at the end of the projection room, which was farthest away from the screen and in which the technicians sat with the microphones, etc. The lecturer also dealt with the requirements of other buildings.

Electric Supply to Bombay City and Surroundings[3]

Mr. P. E. Golvala in the Chair.

Mr. V. R. Vaidya in introducing his paper said that the city of Bombay and the neighbouring areas receive electricity from the Hydro-electric power stations situated at the foot of the Western Ghats, about 40 to 80 miles away. There, on the top of the Ghats, rain water is collected during monsoon in large artificial reservoirs, and this water is directed by suitable pipe lines throughout the year to power stations at the foot of the Ghats ; the water by reasons of its high head and consequent potential energy drives large hydro-electric turbo-alternators and generates electricity, which is transmitted to Bombay and utilised in various forms—for providing domestic lighting and heating to the public, for running the electrified railways and trams, and for driving the great industries of this City, like textiles and miscellaneous factories. It is an interesting subject, to know

3. A paper read by Mr. V. R. Vaidya at a General Meeting of the Bombay Centre held on the 17th February, 1941.

the elements of this electric supply system, which is responsible to a large measure for the wealth, happiness and welfare of our City.

The Tata Hydro-Electric System.—The interconnected Tata Hydro-Electric System was developed in stages. The first hydro power house, transmission and distribution system came into service in the year 1914, when the Tata Hydro-Electric Power Supply Company transmitted energy from the Khopoli Power Station to Bombay. As the load developed, the generating station at Bhivpuri of the Andhra Valley Power Supply Company next came into operation in the year 1922. The third generating station at Bhira belonging to the Tata Power Company, began supplying load in the year 1927. These three Hydro-Electric Power Stations, interconnected with each other, supply all the energy required in Bombay and the surrounding places like the Suburbs, Poona, Thana, Kalyan, Bhiwandi, Ambernath, etc.

The main features of this interconnected Hydro-Electric System are given below :—

	HYDRO			ANDHRA	POWER
	Shiravta Lake	Walwhan Lake	Lonavla Lake		
Catchment Area-Square Miles ...	11	5·5	5·4	48	95·6
Area of Lake at F.S.L. Sq. Miles ...	5·05	2·4	1·5	12·5	14·85
Capacity in M.Cu. ft. above draw-off level ...	6567	2560	414	12850	16120

				Dam	Waste Weir	Main Dam	Aux. Dam
Length of Dam. Incl. Waste Weir	7606′	4455′	3615′	2450	2432	2200	5123′
Section of Dam at top	12′	4′	3·5′ – 15′	15′ – 5′	18′		
Section of Dam at Lake bottom	51·2′	40·8′	17·5′	17′	148′	11′	98·6′
Height of Dam above river bed	83′	71′	34·5′	22′	130′	17′	146′

	HYDRO	ANDHRA	POWER
Tunnel Length	5000′	8700′	14850′
Duct Line Length	,, 22850′		
Pipe Line Sizes	2×82½/72″; 6×42/38″;	6×42″ 6×38″	3×84″ 5×58/51″ 10×36″
Pipe Line Lengths	2 each 8200′	6 each 2310′	3 each 140′
	6 each 4300′	6 each 2290′	5 each 3670′
			10 each 2071′
Total	12500′	4600′	5880′
Max. head-gross	1726′	1743′	1655′

	HYDRO	ANDHRA	POWER
Number of Generators	6	6	5
Size—kW (Normal)	8000	8000	17500
Total kW	48000	48000	87500
Generator Voltage	5000	5000	11000
Step-up voltage ratio	5000/100,000	5000/100,000	11000/110,000
Transmission Voltage	100,000	100,000	110,000
Number of Circuits and route miles	To Bombay	To Bombay	To Bombay, 2×76
Transmission lines	1×43	2×56	To Poona 2×43 To Chola 2×1·6
Tie Lines between Khopoli & Bhivpuri	1×19		
Tie Lines between Khopoli & Bhira	1×25		
Tie Lines between Dharavi & Parel	2×7		
Conductor Area	Copper ·2	Copper ·095	Copper ·095 Copper ·2 ACSR ·1045 Dharavi Kalyan.
Voltage ratio of step down transformers	85800/6600 85800/23100 85800-23100	85800/23100	89725/23100
Distribution Voltage	6600 and 22000	22000	22000 22000 Poona 3300 V.

Generation and Transmission.—The Electricity is generated at 5000V. at Khopoli and Bhivpuri and at 11000V. at Bhira Power Station and is stepped upto 100,000 volts. At this voltage it is transmitted to Bombay, Kalyan and Poona. In Bombay, the energy is received at Dharavi and Parel Receiving Stations and is stepped down to 22000V. at Dharavi; and to 6600V. and 22000V. at Parel. Similarly at Kalyan, the supply is stepped down to 22000V. and at Poona to 3300V. The Electricity at these reduced voltages, is ready for distribution to Industries, Railways and Distributing Licensees.

Distribution : (a) Industries.—The Industries, like textile mills including silk and woollen mills, flour mills, ice factories, oil and rubber works and engineering workshops form the bulk of the load on the Hydro-Electric System ; they consume nearly

100,000 kW. Each mill or factory has a sub-station in its compound where power is received at 22000V. or 6600V. A.C. and stepped down to 2200V. or 400V. A.C. and distributed to the motors for driving the line shafts and machinery.

(*b*) ***Railways.***—The B.B. & C.I. Railway are supplied from Dharavi and Kalyan at 22000V. A.C ; underground feeders are laid between Dharavi Receiving Station and B.B.& C.I. Railway Sub-stations at Grant Road and Bandra ; and overhead lines, between Tata's Kalyan Sub-station and B.B.& C.I.'s Bassein Road Sub-station. At these Railway Sub-stations, electricity is converted from 22000 V. 3-phase A.C. to 1500V. D.C. and supplied to the overhead catenary for driving the suburban trains between Churchgate and Virar.

The total load is about 8000 kW.

The G.I.P. Railway are also supplied from Dharavi and Kalyan. From Dharavi, 22000V. A.C. underground cables run to G.I.P.'s Kurla and Wadibunder sub-stations. From Kalyan, 22000V. 3-phase overhead lines transmit the supply to G.I.P.'s Thana and Kalyan sub-stations. These four sub-stations convert the 22000V. A.C. energy to 1500V. D.C. and supply the overhead catenary for running the suburban trains between V.T. and Kalyan and Bandra over main and harbour branch lines.

Also, two short 100,000V. overhead lines between Tata-Kalyan and G.I.P. Chola interconnect the G.I.P.'s 100 kV. overhead system from Chola with the Tata Hydro-Electric System ; over these circuits, the hydro-electric energy is transmitted at 100 kV. from the Tatas' System to the several G.I.P. sub-stations along the Kalyan-Poona and Kalyan-Igatpuri Railway lines. These sub-stations convert the energy from 100,000V. A.C. to 1500 V. D.C. and supply it to the electric trains from Kalyan to Poona and Kalyan to Igatpuri.

The total G.I.P. load is about 30,000 kW.

(*C*) ***Distributing Licensees.***—Among the distributing Licensees, who obtain their requirements in bulk from the Hydro-Electric System and distribute to the general public for domestic consumption and small motive power, are the B.E.S. & T. Co., Bombay Suburban Electric Supply Co., Poona Electric Supply Company and others such as Thana, Kalyan, Bhiwandi, Panvel, etc.

B.E.S. & T. Company.—This organisation which is responsible for supplying electricity for the purpose of domestic and limited motive power in Bombay is supplied in bulk from the Hydro-Electric System at 6600V. or 5500V. A.C. at seven receiving points located in different parts of the City.

They are :—

1. ***Kassara Sub-station***—located near Mazgaon, receives supply from Tatas' Parel Receiving Station and distributes to a large number of static sub-stations at 5500V. 3-phase A.C. The greater part of Bombay-South receives supply from this sub-station.

2. ***Esplanade Sub-station***—located near Dhobi Talao, receives supply from Tatas' Parel Receiving Station at 6600V. A.C. It distributes to surrounding localities and feeds the tramway trolley wires ; the latter are supplied at 600V. D.C.

3. ***Backbay Reclamation Sub-station***—near Churchgate Railway Station, receives supply from Parel at 6600V. A.C. and supplies to the new buildings in the Reclamation Area.

4. ***Suparibag Sub-station***—in Parel, receives supply from the Parel Receiving Station at 6600V. 3-phase A.C. and distributes to surrounding areas.

5. ***Lalbagh Sub-station***—also in Parel, receives supply from Parel Receiving Station at 6600V. and supplies neighbouring areas and to the overhead trolley wires for trams.

6. ***Kingsway Sub-station***—in Dadar (G.I.P.) receives supply from Tatas' Dharavi Receiving Station and supplies to Dadar and Matunga (G.I.P.) and to the tramways.

7. ***Mahim Sub-station***—in Dadar (B.B. & C.I.) receives supply from Dharavi Receiving Station and supplies to Dadar, Matunga and Mahim (B.B. & C.I.) areas. The total load of the B.E.S. & T. Co. is about 33000 kW.

The Bombay Suburban Electric Supply Company—receive energy at Dharavi Receiving Station and transmit it to their step-down sub-stations at Kurla and Bandra. The Bombay Suburbs are supplied at 400 and 230V. A.C from these two principal sub-stations and other subsidiary sub-stations.

The Bombay Port Trust—is supplied from Parel Receiving Station at 6600V. at their several sub-stations, from where the energy is utilized for pumping, lighting, workshops and other dock services.

The Poona Electric Supply Company's Sub-station—at Poona is supplied by two 100 kV. overhead lines from Khopoli Power Station. This is stepped down to 3300V. A.C. at Poona sub-station and delivered in bulk to the Poona Electric Supply Co.

Small Licensees—like Thana, Kalyan, Bhiwandi, Ambernath, etc. are supplied at 22000V. 3-phase A.C. from overhead lines from Tatas' Kalyan sub-station. Energy is stepped down at these sub-stations to 400-230V. A.C. or otherwise suitable voltage and distributed to the Public by the Licensees.

Gentlemen, this brings me to the end of my lecture, wherein I have tried to describe the various components entering in the subject of power supply to this City. In our survey, we began with rain water, and covered the lakes, dams, pipe lines, hydro-electric power stations, 100,000V. transmission lines, primary stepdown sub-stations from 100,000-22000 and 6600V., secondary step-down sub-stations from 22000 or 6600V. to 2200 or 400V., or from A.C. to D.C. and have ended with the lights and fans in this very room, which make so much for the brilliance and comfort of our gathering this evening. As the object of this talk is to make it informative and interesting to engineers of all professions and not to electrical engineers only, I have avoided giving you elaborate facts and statistics and have confined myself mostly to a narrative account of the hydro-electric system which supplies us with electricity. I hope I have been successful in my efforts to convey to you the information on this subject satisfactorily.

Electricity & Progress.—Before closing, let me describe the part, which the systematic development of hydro-electric resources in this part of the Presidency, has played in the general acquisition of wealth and material prosperity for the community. Bombay derives its power supply from three separate power stations, separated miles apart but inter-connected with each other, and situated in quiet and disturbance-free localities. This power is transmitted to Bombay on five separate 100,000V. lines and every primary and secondary sub-station is furnished with duplicate feeding arrangement. In brief, every reasonable precaution has been taken to provide

for continuity and security of supply, so that the industry, transport and public welfare, may continue to progress without any interruption.

There are several ways of judging the progress of a City or population and one recognised method is to compare the electric consumption from year to year. I therefore give below the energy consumption of Bombay City for the past twelve years and request you to judge from this table, the highly important part which Electricity has played in the development and prosperity of our City :—

Year.	Total energy Sales.	Index figure, taking 1928-29 consumption as unity.
1928-29	325·9 Million kWh	1·00
1929-30	393·4 ,, ,,	1·21
1930-31	394·3 ,, ,,	1·21
1931-32	424·6 ,, ,,	1·30
1932-33	413·2 ,, ,,	1·27
1933-34	377·5 ,, ,,	1·16
1934-35	472·1 ,, ,,	1·45
1935-36	492·4 ,, ,,	1·51
1936-37	503·4 ,, ,,	1·55
1937-38	612·8 ,, ,,	1·88
1938-39	626·4 ,, ,,	1·92
1939-40	610·4 ,, ,,	1·87 Consumption was affected by textile strike.

J. N. Tata's Enterprize.—In the end, Gentlemen, I wish to invite your attention to the fact that we, as engineers of to-day and the future have a right to be proud of this highly developed Hydro-electric system of Bombay, which is an Indian enterprize and is manned by Indian Engineers. About the end of the last century, Mr. J. N. Tata, one of the greatest of our countrymen, foresaw the possibility of hydro-electric development in this Presidency, and despite difficulties and opposite counsel, pursued his ideas with his indomitable vigour, until they took root and brought forth this giant tree after his death, which has helped materially to build up the wealth of this great

City. Mr. J. N. Tata was almost a prophet, and a person of extraordinary talents combined with rare vision. He foresaw the industrial future of India with a vision that no one else possessed, and despite tremendous odds, laid foundations of two of the most vital industries of our country, *viz.*, Iron and white coal, *i.e.*, hydro-electricity. You will be surprised if I may tell you that this white coal or hydro-electricity conserves nearly 400,000 tons of our national resources of black coal per year in Bombay alone and thereby also prevents the City atmosphere from being polluted by smoke and carbon dioxide and contributes very substantially to the health, wealth and happiness of our great City. I therefore end this talk with a respectful tribute to the memory of this great personality, and pray that his example may inspire us in the future.

Some Track Maintenance Practices Abroad[4].

Mr. J. H. Talati said that as he had been visiting different railway works in England just prior to the war, the visits were perforce short and hence very detailed information could not be obtained. Also for want of a projector, the lantern slides could not be shown to the audience and hence a small album was circulated round for information.

He first described the permanent way and fixtures as adopted on different British railways and on Pennsylvania Railway, U. S. A. He then gave a short description of some of the novel features of a railway project of putting two additional lines between North Acton and Ruislip on G. W. Railway in England. This Railway devised its own methods for obviating the difficulties caused on account of London clay which was similar in character to the Indian black cotton soil. In making up the bank, the Railway had provided a toe of special material and after making the formation, top dressing of selected material was given to afford easy drainage. In certain cases, toe walls with perforated or open jointed drains were provided.

The lecturer then described the main carriage shop at Ruislip, a large structure occupying about 5½ acres.

Turning to the maintenance methods, he said that measured shovel packing was adopted on most of the English Railways while the Southern Railway had made its own improvement on

4. Brief resume of a lecture given by Mr. J. H. Talati, A.M.I.E., G.B.S. Railway, Baroda.

the process for effecting economy in time and cost. He particularly mentioned that drawing office was liberally made use of in all proposals of renewals. When any set of points and crossings was to be changed, possible future alterations to meet with traffic requirements were looked into and curves were eased as far as possible. The drawing office had its share even in re-adjusting the curves as found necessary by looking to the diagrams received from the track recording instrument tests.

He further mentioned that welding was widely adopted for repairing points and crossings on British Railways. The L. M. S. Railway was however of opinion that oxy-acetylene welding was found more suitable from considerations of crystalline structure which was disarranged in electric welding to a greater extent on account of greater temperature generated. He also mentioned that on American Railways, the battered ends of rails were frequently repaired by the oxy-acetylene process and the rail ends were discarded by cutting only after two or three repairs. The L. P. T. B. Railway in England had a big workshop with special facilities to weld rails upto a length of 300 feet by flash welding process.

The Speaker further added that the use of concrete both for maintenance and construction jobs had great possibilities in India as found from his different visits in the concrete yards of the three major railways in England. He referred the audience to his article in the *Indian Concrete Journal* of April 1940.

He closed his talk by giving the wage standard of gangmen, mates, Permanent Way Inspectors and welders in England as well as in America.

Mr. K. C. Bakhle[1] welcomed the introduction by Mr. Talati, the Speaker of the evening, of a paper connected with Railways, especially as such subjects rarely come in for discussion at the Bombay centre. He referred to the various types of permanent ways existing on the G.I.P. Railway, and gave some details of sections and weights of rails, types of sleepers, wooden, steel, trough and cast iron pot and plate sleepers. He drew attention to the fact that rails as heavy as 115 lbs./yd. were in use on certain railways in India.

1. Divisional Engineer, G. I. P. Ry.

2. Referring to a point raised by a previous Speaker during the discussion, whether it was not desirable to have a standard heavier than 90 lbs/yd. for rails on the broad gauge system in India, he pointed out that it was not entirely correct to state that the strength, more especially lateral strength, of a track was dependent upon the weight and section of rail alone. It had been proved that the number and type of sleepers, fastenings, ballast and even the period during which the bed has been left undisturbed were other important factors, so far as the resistance of the track to side displacement was concerned.

3. Mr. Talati had mentioned that whereas Railways abroad had specialised sections to go into the question of realignment of curves, the tendency in India was to leave this important matter to P. W. Inspectors. Mr. Bakhle explained in brief how tracks on curves gradually lose correct alignment, and how on the G.I.P. Railway it was principally the work of an engineer to decide the realignment of curves. He suggested that though speeds in India were generally not so high as in some foreign countries, they were high enough to justify extra attention being paid to the running specially on curves.

4. He spoke of the efforts made by L.M.S. Railway in aligning their main line curves from London to Edinburgh before that Railway introduced their high speed non-stop runs and the effective use that was made by the study of comparative charts taken with the Hallade machine.

5. Regarding measured shovel packing Mr. Bakhle stated that this was possible only on tracks laid with wooden sleepers, since it was necessary to jack up the track to spread the measured quantity of stone chips under the rail seat. Such a method could not be used in the case of troughs, pot or plate sleepers, because when the track was lifted, the packing inside the cups would tend to run out. Jacking of a track carried on semi-rigid sleepers, like pots or plates which were connected merely with a tie bar, would further tend to disturb the fastenings and their adjustments.

6. Reference had been made in the course of the discussion to the Hallade Recorder, the Dynamometer Car and Mr. Mulleneux's Track Recording Car. Having personal knowledge of these, Mr. Bakhle explained that all these instruments were aids to engineers in specific directions. Attention to

problems connected with the stability of locomotive on track, and with their mutual actions and reactions came to be focussed first of all in France after the 1914-18 War. The Railways in France were then in an unsatisfactory state of maintenance. Little or no money, materials or labour had been expended on maintenance during the 4 years of war, and as a measure of reparations, France received a number of German locomotives, many of which were of the 'Pacific' type. These, by their very design, demanded a well-maintained track, and much valuable scientific research was carried out in France subsequent to 1918.

7. The Hallade Recorder was the invention of a Frenchman, but the further knowledge gained by the French railwaymen had, in 1938, reached the stage where they had scrapped the accelerometer of Mons. Hallade, and had resorted to more accurate instruments which gave quantitative and measurable results. The Hallade instrument was, however, still used by many railways, and a comparison of charts of two runs made under similar conditions afforded a measure of testing the results of work done.

8. The Dynamometer Car, as its name implies, is a measurer of power, and this car has been used more exclusively in recent years on trials connected with the performance of locomotives ; it had not been used to any known extent for measuring or recording track defects.

9. Mr. Mulleneux's Track Recording Car is one fitted with apparatus which measures directly and records certain defects in the track and is therefore of much value to the open line engineer and his permanent way staff. It again has its limitation, for it records the state of the track under its own wheels, which carry an axle load of about 10 tons. A previous speaker had referred to track defects which were visible to the eye, and others he had classed as "invisible". Mr. Bakle preferred to call these latter, defects of a track *under load.* The Track Recording Car measures defects of a track under its own load, and though this knowledge is better than no knowledge hidden under "invisibility", behaviour of the track under vertical and often lateral load of a 19 ton axle of a locomotive travelling at high speed can not be measured by the Track Recording Car.

10. Mr. Bakhle was glad that Mr. Talati had read out figures of salaries paid to permanent way staff in other parts of the world. Members present had probably a very good idea of

what corresponding salaries were being paid in India. There seemed to be impatience shown in certain circles as to the rate of progress being made in railway technique and operation, but Mr. Bakhle stated that the Railways too, quoting the old phrase, had to cut their coat according to their cloth. He also wished to see greater advance in many directions in railway matters; it had been said that "Any fool can design a house at a cost, but it takes an engineer to design it at a resonable and economic cost." The same applied to the Railways in India.

Mr. K. N. Lilaoowala[1], A.M.I.E. said that the question of track maintenance demanded a high standard of efficient work in the present day of rapid development of transport and the demand for the greater comfort of the travelling public. The maintenance problem was dependent on the susceptibility and conscientiousness of human instincts in detecting the defects.

The Railway Board decided to have the tracks checked by some mechanical means and so the first Dynamometer Car was adopted in 1930.

The Hallade Recorder—invented by the French engineer Jean Hallade is used on many Railways for the purpose, and depends for its action on various movements of pendulums which actuate the pencils on the moving chart. The amplitude of the motions would decide the defects, but the location of the defects becomes essential thereafter. The results obtained with this recorder are affected by the carriage springs. However to avoid all difficulties Mr. H. J. Mulleneux, Chief Electrical Engineer of the G.I.P. Ry. had designed a track recording car actuated by various electrical circuits, in 1939.

The defects of the track are,

(1) Low rail joints which cause jars,

(2) Uneven variation of gauge or faulty alignment or faulty curvature which cause jolts or lateral swinging,

(3) Faulty packing of the ballast or faulty superelevation of curves or faulty transverse levels which cause rolling.

Mr. Mulleneux utilised a standard bogie weighing 40 tons. Small tanks containing whitewash were suspended under the bogie, and compressed air of 50 lbs./sq. in. was admitted in these tanks. If the defect of the track exceeded the limits fixed by the Railway authority the closing of the electrical circuit

1. Electrical Engineer, Moon Mills, Bombay.

would instantaneously operate the valve and spray the whitewash on the defective track. One pint of whitewash produced mark 10 ft. in length and took only 1-10th of a second to spray it and the mark was within 10 ft. of the defect. The operator sits on a central table carrying all instruments and there are mirrors fixed on both sides through which he can see the tracks from his fixed position. Any undue defect of the track above the fixed limit would cause a horn to blow and a signal to go up drawing his attention so that through the mirrors he can see the whitewash mark on the track and jot down the post number. The recording paper strip is worked from the axle and its speed is so adjusted that an 8 in. feed of the paper is equivalent to one mile of track. The gauge detector depends for its action on two powerful electromagnets suspended above the rails and follow it faithfully when energised. The variation of the gauge will cause the magnets to move and thus disturb the balance of an electromagnetic circuit. This disturbance is recorded on the chart and a continuous record of the gauge is thus provided. The exact speed of the bogie at any point can be exactly determined by an ingenious device, which consists of an energised electrical circuit which sets up a spark of 4000 volts every 15 seconds. This spark produces a puncture on the chart and by measuring the distance in inches between two such punctures and multiplying the same by 30 we get the speed in m.p.h. at that point.

This recorder not only records the defects of the track independently by electrical means, but it also records the effect of the heavy bogies moving at certain speeds on the track. We are indebted to Mr. Mulleneux for his ingenious design.

In replying to the discussion, the Speaker referred to his visit to the White Wash Train of the Great Western Railway in England and said that due to higher speeds, it was the experience of the British Railways that the current spot where the depression happens was not noticeable.

In replying to Dr. Shiv Narayan's remarks about electric locomotives, the Speaker regretted that he had no experience of these, and further mentioned that as far as his information went, the Report on the Bhita Inquiry made no mention about heavier section of rails.

Regarding Mr. Bakhale's criticisms, he thanked him for his valuable references which filled up all the drawbacks of the Speaker's paper.

Hyderabad Centre.

Experimental Investigations Regarding the Nature of Flow in the Arched Vents of Deep Submersible Bridges During Floods.[1]

Problem.—In the design of submersible bridges with arched vents it is customary to assume that during floods the vents run full and hence in the calculation of stresses upon the arches of the submersible bridges and its supports no allowance is made for the superincumbent weight of the water, on the supposition that the downward thrust of the water on the arch is approximately balanced by the upward thrust of the water in the vents, ignoring the thickness of the arch in accordance with hydrostatic law.

The object of the experiments was to investigate whether the assumption of the vents always running full, was correct or not, and if not correct to study the actual conditions of flow and determine, if they demand any departure from the usual practice in the design of submersible bridges, especially those with a large depth of water flowing over them up to 20 or 30 feet or even more.

The Chief Engineer in a note on the subject stated the problem as follows :—

"Prima facie the arch should be in a state of static balance, provided the difference of level between the upstream and downstream levels of water is negligible. The obstruction caused by the structure in the natural section area of the river bed is so slight that the velocity remains practically unaffected. In my conception these conditions do not obtain and my reasons are as follows:—

"The upward thrust is in action so long as the depth of flow is flush with the roadway. As this depth increases above the roadway, two conditions at once set in and magnify progressively. One is the increase in velocity through the vent accompanied by sudden contraction and increased resistance along the periphery of the vent resulting in eddies and consequent disengaging of air from water which is likely to collect along the highest part of the barrel and from a dividing line between the undersurface of the highest part of the arch and the upper surface of the column of water passing through the vent. The analogy of this phenomenon is to be found in the flow of water through closed conduits. It is generally seen that the moment the stream-line flow is disturbed by the interposition of an obstruction the velocity exceeds the critical limit, the air mixed with water disengages itself and collects at the highest point of conduit."

1. A paper read by Dr. S. P. Raju, A.M.I.E. at the 3rd Annual General Meeting, Hyderabad Centre on 15th December 1940.

"If such a condition sets in, for the evidence of which there appears to be ample factors, the under column of water is, at least, not in constant and continuous contact with the under surface of the structure."

"My other conception is, that when the structure is fully submerged, the roadway of the bridge acts like weir with a broad crest. As the down stream water is a deep and slow moving stream a standing wave will occur, the size and position of which will largely depend on the amount of energy to be dissipated. In such cases, as the upstream depth is very little greater than the downstream depth, the wave is bound to be small and close by or within the barrel. The back rollers are assumed to destroy the contact with the undersurface. Such an action is not presumed to travel along the whole of the barrel. If any part of it is affected, however small, and even instantaneously, the forces of instability are let loose which need to be guarded against and provided for in the design."

"For considerations stated above, the underside pressure has been fully neglected and the superimposed load over the bridge has been assumed as the column of water passing over it."

Preliminary Studies.—Preliminary studies were made by the Author in the glass flume in the Hydraulic Laboratory with a model of the dimension approved by the Chief Engineer. A

Fig. 1. The Glass Flume
in which the preliminary experiments were carried out.

series of investigations were carried out in order to get an idea of the nature of flow in the vents and its susceptibilities to change certain variables, like the intensity of the flood, discharge, downstream level, etc.

The results of these investigations were shown to the Chief Engineer on 28th September 1939, and as it was found that it was worthwhile to carry on the investigations further,

it was decided to take the actual case of a submersible bridge either constructed or designed and carry out experiments on a suitable model of the prototype with definite fixed data.

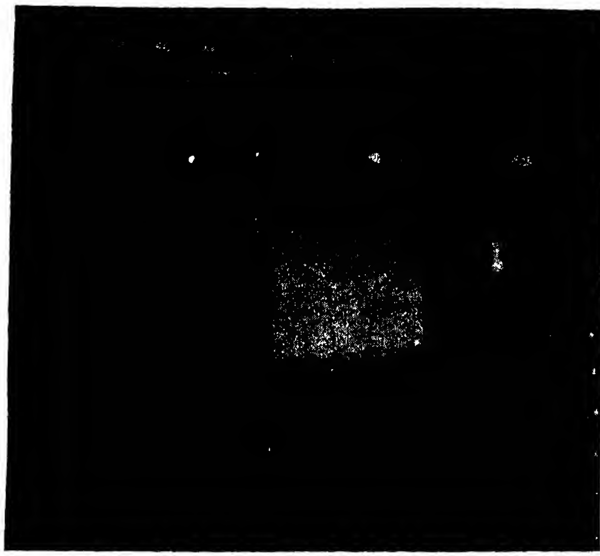


Fig. 2. The Model used for Preliminary Studies.

Accordingly the Chief Engineer sent the Author blue prints of a design of submersible bridge with about 20 ft. depth of water flowing over it, and a note stating his conception of the case and the problem to be investigated, from which an extract of the relevant portion is quoted above.

The Prototype.—The Prototype selected by the Chief Engineer was a submersible bridge proposed to be constructed across the River Krishna at Tintini. The following data was provided :—

Drainage area	...	20,500 sq. miles
Maximum discharge		600,000 to 700,000 cusecs
Bed level	...	954·00
Road level	...	984·75
Maximum flood level	...	1002·67
Afflux level	...	1004·10
Flood depth	...	50·10 ft.
Depth of water below roadway	...	30·75 ft.
Depth of flow over roadway	...	19·35 ft.

The submersible bridge was to consist of 56 spans of 30 ft. each with segmental arches having one-fourth rise designed for 20 ft. head of water over the roadway including afflux. The road level itself was to be 30·75 ft. above the bed level.

The Model.—In order to facilitate the observation of the character of flow inside the vent, the model was made to represent only half a vent with half the pier, the vent side being fitted against a glass wall through which movement of the water could be seen.

Fig 3. The Model of the Submersible Bridge at Tintini.
Placed in the Experimental Channel.
(Looking upstream.)

Taking into consideration the space and the water available in the Laboratory, the model was determined to be made to a scale of 1 in 36. • According to this scale the width of the model was 6 inches, the depth between the road level and the bed was 10·25 inches while the depth of the flood over the road level was 5·97 inches.

The length of the prototype represented in the model was 18·5 ft. consisting of :—

1.	Half the span of 30 ft.	...	15·0 ft.
2.	Half of the thickness of ordinary pier 7 ft.	...	3·5 ft.
	Total	...	18·5 feet.

Experimental Channel.—The model was fixed in a cement plastered channel of the same width as the model (6 inches) and 20 ft. long. The vent side of the channel at the model was faced with glass so that the nature of the flow not only in and above the vent but also for some distance upstream and downstream of the model could be observed. The length of the channel on the downstream side was kept 16 ft. long, so that the effect of conditions of discharge like the surface fall and turbulence may have no effect upon the flow near the causeway.

Conclusions.—While there are still some aspects of the problem under investigation, sufficient evidence has been found to enable the determination of the design of the Tintini bridge with reference to the question of allowing, or, not allowing for the nearly 20ft. depth of water above the submersible bridge.

As stated by the Chief Engineer the crux of the whole problem was the determination of the difference of pressure due to water between the crown of the arch and the roadway vertically over it. To do this, arrangements were made for the

Fig. 4. The Model Showing Pressure Points.

simultaneous measurement of pressures at various points at three sections, one near the upstream end of the model, one near the downstream end and the other in the middle of the model. The results were illuminating and contrary to expectation.

(1) For slow rates of rise of floods of low maximum discharge the vents of the bridge run full and the pressures follow practically the hydrostatic law, the pressure at the crown being greater than at the road level indicating a *resultant upward thrust.*

(2) But for rapid rates of rise of floods of high maximum discharge, there seems to be justification for the apprehension of the Chief Engineer. The vents do not run full for sometime even when the water is flowing over the roadway and the pressures do not follow the hydrostatic law. On the contrary under certain conditions the pressures at the crown are even lower than at the road level, indicating a *resultant downward thrust,* which would need making allowance for the superincumbent weight of water either partially or fully.

The conditions of flow, however, at the Tintini Bridge fall under the first case, and need no allowance for the weight of water on the top. On the strength of the results of these investigations the Chief Engineer had the designs altered.

Full details of the results including the nature of flow under different conditions, variations of pressures and velocities, etc., will be given in a subsequent paper after the completion of all the investigations.

Rural Electrification and Industrial Development in H. E. H. the Nizam's Dominion.[1]

Nawab Ashan Yar Jung Bahadur in introducing his paper said that several schemes such as the Godavari, the Upper Kistna; etc., had been investigated by the P.W. Dept. of H.E.H. the Nizam's Dominion with a view to utilise the national resources of the State for the development of industries, as provision of cheap power has been regarded as one of the progressive means towards industrial advancement.

1. Excerpts from a paper presented by Nawab Ashan-Yar Jung Bahadur, M.I E. at the 3rd Annual General Meeting at Hyderabad, Deccan.

The Author then outlined the available power resources in the State as follow:—

Name of project	Power available in kW.	Remarks.
1. Godavari	65,000	Preliminary investigation completed
2. Lower Kistna	50,000	Under investigation
3. Tungabhadra	40,000	Preliminary investigation completed
4. Upper Kistna	30,000	Do. Do.
5. Lower Manjira	21,000	Under investigation
6. Lower Manjira	3,000	Detailed estimates ready
7. Kaddam	4,000	Preliminary investigation completed
8. Purna	3,500	Under investigation
9. Painganga	3,500	Do.

He then referred to the application of this available energy in H.E.H. the Nizam's Dominion to the development of electro-metallurgical, electro-chemical processes, railway and rural industries.

With regard to electro-metallurgical industries he referred to the production of high grade steel, as extensive magnetic iron ore deposits are available in the Godavari valley.

Under the electro-chemical industries there was the scope for the production of artificial fertilisers such as ammonium sulphates and nitrates, the manufacture of heavy chemicals such as caustic soda and chlorates, etc.

Railway Electrification has been another source of economic effects, and the Author visioned the possibility of electrification of the broad gauge line from Bezwada to Bellarshah—a distance of 282 miles. The Author added that all the projects mentioned above were of medium head schemes varying from 100 to 300 ft., which was a point in favour of irrigation development.

The whole scheme has been based upon the proposed "grid" system in link with thermal plants, utilising the Shasti Bellampalli and Kothagudum coal mines. The Author then made an analysis of the advantages of this combined system and its application also to the agriculture and cottage industries.

He concluded his paper with the following recommendations :—

1. Creation of Central Electricity Board composed of engineers, industrialists, and businessmen together with Government officials.

2. Appointment of a Research Committee to encourage industries.

3. Government to advance financial aid.

4. Suitable relations with foreign experts to obtain their assistance.

North-West India Centre.

The Co-ordination of Technical Education in India[1].

There are three parties principally concerned with technical education in this or any other country. They are the school, the college and the employer. They are engaged in producing young men who will be able to take their places in industry as artisans, foremen or executives. The artisan is the product of the primary school, the foreman of the junior technical school or technical high schools and the executive of the university or technical college. This ordering is in no sense exclusive ; a primary school boy with ability may be expected to pass the entrance examination into a technical high school and on completion of his six years course there, from the age of eleven, pass on at the age of seventeen to the engineering department of a technical college, polytechnic or university. The university, on the whole, tends to turn out a more academic article than the polytechnic, with the result that the former leans towards research and the latter towards the managerial posts in industry. We have, then, three types of students; the foreman type, the managerial type and the research type. Executives are drawn from both the latter groups. But each of these groups should have its own type of qualifying examination and award and each in its own group should be national in character and value.

The whole of industry is open to the boy with ability and the desire to apply it. When a boy leaves a technical high school such as I am at present engaged in creating in Delhi he normally goes into industry earmarked for further training in the works and at the technical college, to prepare him to fill the key position of chargehand, foreman, jobber or tackler, as

1. A paper read by Mr. W. W. Wood before the N. W. I. Centre on 14th March 1941.

the case may be. As you all know, there is an enormous demand in India at present for this important individual, whose duty it is to translate the requirements of the management into solid fact, through the medium of the machines and the men who operate them. They enter the technical high school at the age of eleven and for three years they pursue a course parallel to the same classes in an ordinary high school, except that the treatment of the subjects is more practical. During this period a boy can transfer to an ordinary academic high school if he decides he is not cut out for a technical career and conversely a boy during these years can transfer from an ordinary high school to a technical high school, if vacancies exist. This is an important innovation, even in England, and owes much to the pioneer work carried out in Essex by Mr. John Sargent, Educational Commissioner with the Government of India, when he was Director of Education for that County. Previously boys were admitted at the age of thirteen, when the ordinary high schools had taken the cream of the candidates two years earlier. In India the early age of entry will have the added advantage of accustoming them to use their hands and get dirty faces whilst they are in their most plastic state. During the second three years their general education is continued but 50 per cent to 60 per cent of their time is devoted to vocational subjects such as engineering science, engineering drawing, practical wood, work, engineering workshop practice, dyeing, spinning-weaving and so on, according to the type of technical career they intend to follow in later life. At the end of this school course they receive a certificate which for all practical purposes can be thought of in terms of the Cambridge School Leaving Certificate although, of course, it is the tangible record of a different type of education. This certificate is at present peculiar to the institution that awards it, but as and when more technical high schools are opened in India it may be possible to create an internally set and externally assessed type of examination for these schools of a kind similar to that which I am about to describe and advocate for the products of the polytechnic proper.

Boys are admitted to the senior departments of the polytechnic at and over the age of 17. For five years they pursue either a full-time course or if already engaged in industry, a part-time course of six or seven hours per week. The part-time classes may be taken during the day by arrangement with the employer or in the evening in the student's own time. The former has the advantage that the student is not already tired

after a hard day's work when he comes to class. In my college in England this scheme proved very successful ; one firm alone, who at the outset of the arrangement sent 15 students for one whole day a week, was sending 100 young men each week for a five years' course when I came away. Not only that, but they paid their wages, and if they received good reports, refunded their tuition fees to them also. The five years' courses are divided into two parts : the first lasts three years and the second two years. A certificate is issued at the end of the former and another on the satisfactory completion of the latter. Similarly, for the full-time courses diplomas are awarded at the end of three and five years, which may be regarded as equivalent, in the practical field, to the intermediate and final degree courses.

If a man in Madras wants to employ a foreman who received the theoretical part of his training, after he started in the works or mill at Delhi, he should be able to ask to see a certificate which would be as well-known and have as much value there as here—in other words a national certificate. If an employer in Bombay has before him candidates with degrees or diplomas awarded at Benares, Calcutta or Madras, he should not have to weigh up the value of the respective degrees qua degrees—they should all have equal value. By this I do not at all suggest a common examination—far from it. But what I do suggest is a common *standard*. And I think that your institute can help lead the way. I will take the case of the national certificate for the part-time course first. You will remember that at the outset I said there were three partners in technical education : the school, the college and the employer. To ensure a national certificate scheme of examination collaboration is necessary between the college and the employer. You represent the employers and for this reason I would like to think of every engineer in India as a member of your institute, because that would imply the membership of all the employers—Government, railways and industrialists—and their confidence. In the same way the colleges must make of themselves a national body. With the invaluable and enthusiastic help of Mr. Sargent and Dr. Pandya, Principal of the Bengal Engineering College, I am trying to form an association of principals of technical colleges, polytechnics, and engineering departments of universities and we have already agreed to have an exploratory meeting in my college hall during the later part of July, when Mr. Sargent has promised to take the chair. Finally, the certificate should bear the *imprimatur* of the Central Government as an All-India endorsing body.

It is, in my submission, of very little practical use to award a certificate on the results of an examination only, and this is particularly so in practical as opposed to theoretical education. A young man may have the faculty of cramming for an examination, parrot-wise answering question papers without really understanding what they are all about, and promptly forgetting what he has memorised immediately afterwards. I remember a case in Egypt. The subject was DESIGN. There was a practical project which took a month and a theoretical paper which lasted three hours. One particular student made a hopeless hash of the project but in the written paper gave the answers to some of the questions word for word from my lecture notes. I was rather new to the teaching world and this was my first experience of the "Datus" type of mind. I assumed that he had been cribbing and gave him no marks. When the examination results were published a deputation of students came to see me in my study. The leader pointed out to me that I had been very unfair to their fellow student, as not only were his answers correct but he could recite the whole of my lectures from beginning to end ! Would I test him ? I did, and once he had picked up the cue from the question, he ran on like the babbling brook. Cross questioned, I found, as I anticipated, that he understood nothing of the matter he could recite so freely. It was a lesson I did not forget ; afterwards DESIGN became entirely a tutorial subject. In order to avoid this sort of thing and to ensure that an adequate amount of laboratory work has been carried out, one of the conditions of the award of a certificate should be a satisfactory record of class and laboratory work. You will remember that the student is presumed to be already engaged in industry and only spends $\frac{1}{6}$ to $\frac{1}{5}$th of his time under instruction in the college. It may be taken, therefore, that he is gaining the best available practical experience in operating up-to-date machines and what he most requires is theoretical and laboratory work. This is particularly the case of an ex-technical high school boy, who will have had some six hours per week workshop experience for his last three years at school and will therefore be a reasonably good mechanic before going into the factory. The candidate for a national certificate should be examined by the polytechnic authorities at the end of the first, second and fourth years, and on the results of those examinations should depend his promotion to the third and fifth, the certificate examination years. In Great Britain the former is called the Ordinary National Certificate and the latter the Higher National Certificate.

The question papers for both these examinations are set by the teaching staff and criticised by assessors appointed by the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the Institute of Chemistry or other professional organisation which is the approved examining body for the particular scheme. This arrangement ensures the setting of papers in accordance with an approved curriculum based on the needs of industry in the locality where the college is situated, whilst maintaining a common national *standard* by means of external assessment by a national professional body. At the same time this body is able to watch the content of the papers and see that it does not become academic or drop behind in the exposition of current practice. The examination is conducted where the youth has been trained, so that he has the advantage of familiar surroundings. The assessors reserve the right to attend, and so do the Board of Education inspectors, any of the examinations to see that they are conducted in a regular manner. The examinations are invigilated by the teaching staff, although it is not usual for them to invigilate their own subjects. They also mark the answer papers according to a scheme of marking previously agreed upon with the assessors. Finally, the marked scripts are submitted to the assessors for their comments and any suggestions they may feel disposed to make regarding the allocation of marks. The certificate bears the complete record of the student's training and examination results and is signed by the President of the professional body, the Principal of the training college and endorsed by the Secretary to the Board of Education as representing the administrative and inspecting authority. This is the system I should like to see established here, with the Institute of Engineers (India) as the professional body and the Educational Commissioner representing the Government of India. In the non-centrally administered provinces it would probably be advisable to ask the provincial government to act as an endorsing body also. So much for the national certificate scheme. I ould obviously say a great deal more on the subject but I ink you will agree that details of curriculum and so on are the rovince of a Joint Committee rather than a meeting of this sort, if the idea appeals to you at all. I would prefer to-day to leave some time free for discussion and questions with a view to elucidating any points I have not made clear.

If a full-time engineering course is to take the place of a part-time course a considerable amount of time must be devoted to practical workshop instruction. Such a student, at the end

of his three or five years' course, must be able to take his place in the works with enhanced prestige from the possession of a diploma rather than otherwise. Personally, I think that the part-time system is, on the whole, to be preferred but there are nevertheless cases which justify the provision of a diploma scheme for engineers, and these diplomas should be awarded on the same principles as the part-time course national certificates. A diploma student should have the advantage of first class laboratory facilities and precision machinery, and such courses should not be lightly undertaken by inadequately equipped institutions. For this reason it might be well if they were inspected by the appropriate government department or a small committee of assessors appointed by the professional body concerned before the course for the diploma was approved.

It is impossible to generalise with any degree of safety but at any rate the intention of the certificate course is to produce the chargehand or foreman type, who may go on to a managerial post or even an executive position. He is the type who needs theoretical knowledge allied to manual skill and dexterity, so that he can intelligently accept the orders of the management and convey them with lucidity to the artisan. The line of his promotion is obvious.

The Manager must be a practical man himself. Many of them rise from the ranks. They may lose some of their skill as their administrative responsibilities increase but they have been through the mills and they are the right hand men of the executive. A full-time day course diploma student may rise to management or even an executive position. But if a knowledge of commerce is, as it should be, included in his course, after a short period in the factory to familiarise himself with actual working conditions, he is perhaps more cut out for the sales side—and a very important side it is too—than any other side of the business. If every salesman and sales manager possessed a national diploma the buyers' expectation of life would be considerably increased, although it is only fair to say that the technical knowledge possessed by the average salesman to-day is much greater than it used to be.

There are some industries, sometimes called non-manipulative, which do not require skill in the same measure as, for instance, the production engineer. Sugar refining, the manufacture of soap and vinegar, and tanning are a few examples.

The overseer for this type of industry can best be catered for by a short intensive course of one to two years after he has left high school, whether of the technical or academic type. The mass production processes of manufacture I have in mind call more for basic rather than specific technical knowledge ; industrial chemistry, for instance, can be taught to a syllabus which will meet the needs of the dyer in the textile trade, the tanner and the soap manufacturer. But whether a man is following a full-time day course in engineering, textiles or one of the non-manipulative industries he should, at its conclusion receive a national diploma.

Finally we come to what I consider the legitimate province of the university engineering department as distinct from the technological department. This is, perhaps, drawing rather too fine a distinction but what I intend to convey is the difference between the department which teaches engineering in its wide principles as a subject and the one, like Manchester, which deals with its particular application to certain industries, and more nearly approximates to the engineering department of a technical college. The contents of the examination syllabus and standard of the technological department's degree and that of technical college diploma to which I have already referred should, I feel, be closely related. The university degree in engineering connotes a wider theoretical treatment of the subject, with greater opportunities for experimental and research work. The approach may, with advantage, be more leisurely. The immediate financial return is no greater, but the graduate may very well be regarded as the research worker in industry's own laboratories and the executive of the future. These degrees are usually recognised as entitling the holder to a substantial measure of exemption from the professional body's own examinations, as is the case in regard to your own institute. I should like to see the same idea operating, as it does in Britain, in regard to the National Certificates and Diplomas. How far such scheme could go is not for me to say, but I should think the Higher Certificate might go a long way and the Higher Diploma still farther towards complete exemption for the holder.

To sum up, I suggest that the co-ordination of technical education in India can best be achieved by—

(1) The formation of an association representing all the institutions engaged in technical education in India, the minimum requirement for membership being that

instruction is provided up to the standard of the Ordinary National Certificate. In the first instance such an association might be formed from the principals of the institutions concerned.

(2) The close collaboration of this association with the various professional bodies representing the several branches of technology. In the case of engineering this would, presumably, be your own institute and to make that representation effective it follows that every qualified engineer in India should be a member. Active propaganda to this end is therefore essential and has, I understand, already been initiated.

(3) The appointment of a joint committee representing the colleges, the Institution of Engineers and the Government to draw up schemes for National Certificates and Diplomas.

(4) The creation of a Consultative Committee representing all branches of technical education-teaching, examining and employing to draw up a Policy in Technical Education, which should be revised from time to time at meetings of the Committee held at regular intervals.

The co-ordination of Technical Education in India is an extremely wide subject and for obvious reasons I have confined myself this evening to the consideration of the needs of the engineering industry only. But before resuming my seat I want to touch briefly upon the more general implications of the subject and for this purpose I propose to give you the recommendations made in the Report on "Policy in Technical Education" drawn up by a Joint Committee representing the Association of Technical Institutions, the Association of Principals of Technical Institutions, the Association of Teachers in Technical Institutions and the National Society of Art Masters, published in 1937—

(1) Technical education should be organised on a regional basis. Where the region, regarded as an art, commercial, or industrial unit, embraces areas of more than one Local Education Authority, the arrangements should be such that students in any one Institution, taking the same courses, may be treated alike in regard to fees and conditions of admission.

(2) Co-operation between Technical Colleges, Art Colleges, Commercial Colleges, University Colleges, and Universities should be encouraged and so defined as to secure co-ordination and to minimise overlapping in staffing and equipment.

(3) Continuation Class systems should, in general, be definitely linked up with Technical Institutions. Where the work of the Continuation Classes is not controlled by the Technical Institution organisation it should be organised on an area or regional basis with Co-ordination Committees on which should be representatives of Elementary and Secondary Schools, Continuation Classes, and Technical Institutions.

(4) The provision of full-time senior day technical courses should be increased. Due regard should be given, in the provision of new courses, to the possibilities of absorption of students in industry and commerce.

(5) Pre-Diploma courses extending over one year and leading up to senior full-time day diploma courses should be instituted where necessary.

(6) The provisions of Junior Technical, Junior Commercial and Junior Art Schools as alternative forms of Secondary education should be extended. (The Technical High School includes all these and in addition furnishes the basic education prior to the introduction of vocational bias). Some form of certificate should be instituted for these Junior (or Technical High) Schools, but no external examination should be imposed upon Schools for the purpose of this certificate.

Suitable arrangements should be made for transfer at 13 from one form of secondary education to another.

(7) All young persons should be kept in active touch on a compulsory basis with the educational system until the age of 18 : as soon as possible up to the age of 16 and, in seven years time up to 18, in accordance with the provisions of the Education Act of 1921. Schemes for the development of compulsory attendance at Day Continuation Schools should be organised by specific trades, industries, or occupations, for the country as a whole.

(8) The arrangements made for the full-time instruction of the unemployed juvenile should permit of the closest possible contact and linkage with appropriate evening and day courses in Technical Institutions.

(9) Attendance at part-time day courses of study for advanced students should be encouraged.

(10) Additional facilities should be provided to enable workers in small urban and rural areas who cannot obtain suitable technical education locally to proceed to centres for short intensive full-time courses of training. Similar courses might usefully be provided for workers from certain large centres either in their own towns or at chosen centres, where suitable groups could be collected.

(11) A National scheme of Technical and Art Scholarships should be provided to enable students of sufficient merit and works experience to pass into appropriate full-time day courses of study.

(12) Local scholarship schemes should be developed more widely in order that suitable students may proceed from industry to full-time day course of instruction.

(13) The system of National Diplomas and Certificates, forming a most valuable link between industry and commerce and education, should be encouraged and, where possible, extended.

(14) The grouped course system of the City and Guilds of London Institute should be encouraged.

(15) The teaching of Industrial Administration is capable of wide development, and should receive every assistance.

(16) Short week-end or Summer courses for specialist teachers organised by the Board of Education have proved most valuable and should be extended.

(17) Courses of training in teaching should be made available as widely as possible for part-time teachers engaged in industry and commerce.

(18) Every encouragement to undertake research should be given to teachers capable of carrying out original investigation. In all Technical Institutions doing advanced work, research by a fair proportion of the staff is essential to inspire instruction.

(19) Facilities for physical training and social activities should be extended.

(20) The provision of improved accommodation for technical education, by the erection of new buildings or the remodelling of existing buildings, is essential in many places. New building schemes should provide for progressive modifications and include adequate provision for the social life of students.

(21) Plant and equipment should be maintained on up-to-date lines and adequate financial provision made against obsolescence. Equipment should command the respect of employers and students and be representative of modern industrial practice.

(22) The provision of proper library facilities should receive greatly increased attention. An annual grant should be made for this purpose in order to provide the necessary standard works of reference as well as British and foreign technical and professional journals bearing upon the work of each department.

U. P. Centre

Charcoal Gas Driven Lorries.[1]

Mr. B. K. Bose in introducing his paper said that the use of charcoal and other gases has been extensively developed on the continent of Europe for a number of years. In France in particular this type of vehicle has been brought to a high pitch of efficiency. "The Charcoal" Service Stations of Messrs. Gohm Poulence are to be found every where throughout France. A decree published by the French Government on December 26th 1934, consolidating the various laws concerning the taxation of vehicles laid down that "Vehicles working on compressed or other forms of gas (charcoal anthracite, etc.) are exempt from all taxations. In July 1937, this law was altered and vehicles fitted with gasogenes paid

1. A paper read by Mr B. K. Bose, A.M.I.E. before the U. P. Centre.

only 50 per cent of the taxes on road vehicles. Another law published on 29th June 1938 made the fitting of gasogenes on vehicles compulsory under certain conditions, such as, when one owner has a fleet of lorries working, he must have one vehicle in 15 fitted for charcoal, 2 in 25 and so on up to 10 per cent of his fleet. By similar laws and regulations foreign countries have been developing this kind of fuel power.

Producer gas as a motive power for large stationary engines has been in use for many years. A large number of attempts have been made to evolve small "Gas Producers", which could be attached to motor vehicles which could enable them to run on other fuels than petrol paraffin or crude oil.

Charcoal as a fuel for gas plants has an advantage over any other kind of fuel in that it is free from tar, caustic acids and other impurities, which may cause engine troubles. The only residue is ash. The gas produced does not dilute the lubricating oil, which is thinned by petrol and kerosene oil, nor does it leave any gummy effect on valves and much less quantity of carbon is produced.

The results obtained on charcoal gas fitted vehicles have proved that these vehicles can be operated as efficiently as "Petrol" ones and with much less danger of fire in case of accidents.

The gas plant is an extra fitting to the existing petrol driven vehicle with which the vehicle can be run on charcoal gas, instead of on petrol and the plant can be fitted on any make of petrol driven vehicle.

Producer gas is most reliable and adaptable when charcoal is used as this is the most reactive of all fuels.

The B.Th.U. values of petrol and charcoal gas are about 18,000 and 13,560 respectively. On account of this difference there is a loss in the H.P. of the engine. This loss in power is about 20 per cent. Part of this, approximately 10 per cent can be regained by increasing the compression ratio from between 5 or 6 to 1 and 8½ to 1.

On the other hand excessively high compression ratios are liable to be a source of trouble in as much as the compression pressures increase in proportion with the increase in compression ratio and may go to such extremes as to shorten

the life of the bearings considerably or else be responsible for an excessive wear of the engine. For this reason it has been found advisable not to go as high in compression ratio as the combustion characteristics of producer gas would theoretically allow, but rather stay about half way in between the maximum compression of 8 to 1 and the petrol engine compression ratio, for best overall operating results. This increase in the compression ratio is effected either by machining the cylinder head or increasing the bore, or using flat crowned pistons. If 1/8" is reduced off the bottom face of the cylinder head the compression ratio is increased to 5·95 to 1, but it would be inadvisable to do this as the bottom wall would be reduced in thickness from 5/16" to 3/16". Fitting flat topped pistons would increase the compression ratio to about 7 to 1. This has been found to be quite a reasonable compression ratio. Our tests which were conducted on a 2 ton lorry showed that the machine could be used successfully on gas; and the slight loss of power is in the majority of cases immaterial, as the full power of the engine is seldom developed in actual practice.

To use coal in a combustion engine, one must first of all convert the coal into gas.

The principal reaction of this is

$$C + O = CO.$$

The symbol CO represents carbon monoxide, an eminently combustible gas. The principal reaction is accompanied by a subsidiary reaction which is

$$C + O_2 = CO_2.$$

This CO_2 represents carbon dioxide which being non-combustible absorbs carbon uselessly, and therefore should be eliminated. The product of the first reaction being carbon monoxide at a high temperature gives off its heat to the layers of fuel further away from the entrance of air and the transformation of CO_2 into CO operates by means of these hot layers of fuel.

The reaction is

$$CO_2 + C = 2CO$$

This reaction is one of equilibrium, that is, as the name implies, it can act in either direction and the proportion of combustible gas to the incombustible depends on the

temperature and unfortunately is stronger in gas as the temperature rises, therefore the necessity arises of having a rich gas given off at high temperatures and working at high heat. The result of this has shown a number of troubles when using moveable gasogenes, such as poor generation and high temperature losses, necessitating thick and heavy insulation. To convert CO_2 into CO the suction is so arranged that the carbon dioxide produced has to pass through highly heated charcoal where it absorbs more carbon and becomes carbon monoxide.

The composition of the final gas supplied is as follows:—

N	60%	(Nitrogen)
CO	22·8%	(Carbon Monoxide)
H	8·5%	(Hydrogen)
CO_2	5·2%	(Carbon Dioxide)
CH	2·4%	(Methane)
C_2H	·4%	(Ethylene)
O	·4%	(Oxygen)

If the temperature of a producer is in the vicinity of 450° very little combustible gas is produced, but with temperature in the vicinity of 1000° to 1500°, the maximum possible quantity of combustible CO will be present. Hence the temperature of the producer should be maintained at least at 1000°.

Gas plants are mainly composed of 4 main parts:—

1. ***The Gas Producer.***—This is of a very simple design being only a cylinder of sheet steel having a refractory lining of fire clay. The grate is fixed at the bottom and is made of a heat resisting non-corrosive steel. The cylinder is filled with charcoal and has an arrangement for feeding from the top without opening the fire chamber. The lighting of the fire is done at a point about a foot above the bottom of the grate. A pipe leading from this to the back of the fan at the front of the engine supplies the air necessary for keeping up a bright fire. The suction of the gas is from the bottom of the cylinder below the grate. This system of producing combustible CO requires a large grate area and consequently more space. There is another form of burner in which a jet is used, by which the coal is burnt at a very high temperature at a small place and carbon monoxide is directly produced and does not necessitate the reconversion of CO_2 to CO. But the

arrangement necessary for this system increases the cost of construction a great deal.

2. ***The Cooler.***—The cooling of the gas is done simply by passing the gas through a system of pipes which radiates the heat to the atmosphere. It has been seen that cooler the gas the better the performance of the engine.

The gas that is produced is hot and dirty, which if used by itself would ruin the engine. Very few makers have succeeded in making a perfect filter or cooling plant and this is one of the reasons that use of charcoal has not developed. The Gohm system operates in passing the gas in pipes which run round the vehicle to cool the gas to between 50 and 70°. With proper sections of tubes one obviates all risk of pockets of impurities and obtains a maximum cooling efficiency. This efficiency depends on the rapidity of the circulation, crossing and recrossing. With this arrangement the final temperature of the gas is that of the outside air. This arrangement requires a large area and in cases where the space required is not available a special form of cooler is designed as in the present case.

3. ***The Gas Cleaner.***—The cleaning is easy in case of charcoal because the only residue is ash. The filter consists of three boxes. One is the preliminary filter which is only a small box with perforated pipe fixed in it. The gas circulates and passes through this pipe after depositing the larger particles of ash. It then goes into the second box which is stuffed with coir fibres. This takes up the major portion of the impurities. Finally the gas goes through the third box in which there are cloth bags through which the gas has to pass. The gas which leaves this cloth bag is absolutely free from any impurities.

4. ***The Automatic Mixer.***—The gas cooled and filtered has to be taken to the engine and mixed with a required amount of air to make it explosive. This is the function of the automatic mixer. This is fitted below the usual carburettor of the engine, which starts the engine on petrol gas.

Operations.—The charcoal is first lighted in the fire-box by applying a lighted candle at the inspection chamber marked

14 on the sketch. The fire can be blown up by means of a hand blower in about 10 to 15 minutes. The engine is then started on petrol and the air from the fan keeps the fire alight which is absolutely closed from all sides. After running the engine for a few minutes sufficient gas will be available to change over from petrol to gas. This is done by gradually opening the stop cock on the automatic mixer, which allows the mixed air and gas to go into the engine and at the same time gradually shuts off the petrol inlet. The gas first comes into the first scrubber marked 7 where it deposits the bigger ashes or any coal dust that may have gone along. It then goes to the cooler, where after being cooled it passes through the two filters and then goes through the automatic mixer into the engine. The air gas mixer when once set, rarely requires attention.

The plant works automatically on suction principle in the same way as petrol. No special knowledge is necessary to manipulate or drive a motor vehicle fitted with a gas plant.

On some engines the ignition is so low, that powerless sparks are obtained at the plugs, as the di-electrical characters of the gas are increased through the higher compression, which weakens the ignition spark in the plug. This fault is shown by the engine not coming up to its full speed on gas and at high load and low speed it gradually ceases to ignite, due to the better filling and the increased compression pressure commanded by the low revolutions. In other words due to the high compression, the resistance gets larger. In such cases the fault can be overcome by changing the coil and the plugs to a better quality.

In hill climbing there is a time loss of between 7½ to 16½ per cent whilst in acceleration it varies so widely that mere statement of figures is misleading. Against this loss there is a material saving in cost. In our tests a climb of 1 in 10 was negotiated on second gear without much power to spare. Better results in running and climbing gradients can be obtained by changing the axle ratio of a truck to a lower one.

When charcoal gas is used besides effecting considerable saving in the running cost of stationary and traction engines there is less damage to valves and pistons on account of the lesser degree of heat generated in the ignition chambers and it has also a lesser deteriorating effect on lubricating oils

which have consequently a longer life than on oil driven engines. The starting is done with petrol, but even if no petrol is available it will only take a few minutes more to start the engine on gas alone. Experience with several thousands of lorries that have been in use all over the world shows that a good gas driven engine is reliable and that it will run without frequent breakdowns. The maintenance consists chiefly in cleaning after every thousand miles of run.

The advantages of these gas plants are :—

1. The gas produced is of even quality, homogeneous and best suited for combustion.

2. Works satisfactorily on moist charcoal upto about 20 per cent moisture.

3. Cleaning process is so perfect that no impurities can ever enter the engine.

4. The engine displays greatest effect, when the gas is cold, and the cooling arrangement is such that it is possible to expect the gas to be near enough to the atmospheric temperature.

5. These plants are strongly built and can withstand hard wear and are carefully insulated to prevent heat radiation and every part is available for inspection.

6. They are fool-proof and easy to operate.

7. Lubricating oil consumption is less on charcoal gas than on petrol.

8. The gas produced is far less dangerous than the petrol gas, slightly alkaline and therefore non-injurious to the engine.

I give below the approximate running cost of a lorry or bus on petrol and charcoal gas in a year.

Any new bus or lorry is sure to give a continuous service daily for at least a year without a break. Giving margin of stoppages for two months in the year, due to unforeseen circumstances, it will run for ten months or 300 days in the year.

If the average run per day is 100 miles, in 300 days it will be 30,000 miles.

Quantity of petrol consumed at the rate of 15 miles to a gallon will be 2000 gallons.

Quantity of charcoal consumed at the rate of 80 miles to a maund will be 375 maunds.

Quantity of petrol used at the rate of ¼ gallon per day for starting will be 75 gallons.

Cost of 2000 gallons of petrol in Lucknow is	Rs.	3937 8 0
Cost of 375 maunds of charcoal in Lucknow	Rs.	750 0 0
		3187 8 0
Cost of 75 gallons of petrol	Rs.	147 10 6
Total saving in petrol alone in one year	Rs.	3039 13 6

From this we can see what an enormons saving there is. Practically the price of the lorry is paid up in a year's working. This estimate is very much on the safe side as petrol lorries with loads seldom do 15 miles to a gallon of petrol. Then again with full load there is very much greater wear and tear in the engine driven with petrol than with gas.

In Germany the use of compressed gas as a motor fuel is much more general than elsewhere. Although a few years ago, gas filling stations were to be found only in a few large centres, where they served almost entirely for short distance traffic, by the early part of 1938, the use of this fuel for road purposes had grown to such an extent that there are now some 500 filling stations, either already open or nearing completion. The utilisation of wood gas for power and traction is no longer in the experimental stage. During the last Great War several charcoal gas driven lorries were used in France.

Comparison of Petrol, Diesel and Charcoal Gas Trucks.

PETROL.	DIESEL.	CHARCOAL GAS.
Draws mixture of air and Petrol.	Draws air alone.	Draws air alone.
Compression ratio generally 5·5 to 1.	As much as 16 to 1.	7 to 1 (if more than 30 miles speed is required).
Electric spark to ignite.	Ignition by the high temperature of the highly compressed air.	Electric spark.
Carburettor.	Fuel pump, injectors, etc. and metering devise for injection.	Both petrol carburettor and gas air mixer fitting. It can also be worked on either.
Compression pressure about 90 lbs. per sq. in.	Reaches as high as 600 lbs. or more.	About 75.
B.Th.U. or calorific value is about 18,000.	Far more.	About 13,500.
Initial cost about Rs. 3,000 (before the present rise in prices).	About Rs. 5,500 (due to heavier parts throughout, increase in first cost and of replacement parts.)	Cost with truck complete Rs. 4,500.
Smooth running.	Greater vibration and noise.	Smoother than Petrol.
Ordinary driver needed.	Requires special training.	Ordinary driver.
One quality of Petrol always available.	One quality of Diesel oil not available easily everywhere. Research work for proper grade is not yet complete.	Works on any wood charcoal. But better mileage is gained on good quality.
Carburettor mechanism very simple.	Complicated and special knowledge required. Difficulties are centred in the fuel pump and injection system. Leakage, restrictions, improper metering poor atomisation and incorrect pressures are the principal troubles which not only affect efficient operation but contribute to and directly cause other troubles elsewhere, such as upset combustion, stuck piston rings, bearing failures, etc.	Very simple.

Comparison of Petrol, Diesel and Charcoal Gas Trucks.—*(cd.)*

PETROL.	DIESEL.	CHARCOAL GAS.
(a) Requires attention after 1200-1500 hours run or about 30,000 miles.	(a) Requires a thorough cleaning up, freeing up rings, removing carbon and dirt deposits, spray nozzles, pre-combustion chambers, filter and grinding of valves, after 1000 hours run or about 25,000 miles.	Requires attention at 60,000 to 70,000 miles.
(b) Piston replacements after 3,000 to 4,000 hours run or 60,000 to 70,000 miles.	Major overhauls after another 1,000 hours.	Piston replacements after about 1,25,000 miles.
Cleaning of oils, fuels, filters, etc., rarely.	Must be done more frequently. Fuel filters and spray nozzles must be kept clean consequently.	(a) Generator daily or after a run of about 300 miles. (b) Filter box once in a fortnight. (c) Cooler once in 3 months. All the above are necessary when poor quality of charcoal is used when a better quality of charcoal is used, cleaning can be done after twice the above period.
Starting is easy.	Demand on batteries is heavy and more so in cold weather.	Easy.

TECHNICAL NOTE

Calculation of the Probable maximum flood discharge by Dicken's formula.

For the design of canal works and bridges, it is often necessary to calculate the maximum flood discharge at the site concerned from the catchment area alone. One of the formulae most frequently used for this purpose is Dicken's formula.

$$Q = CM^{\frac{3}{4}},$$

where Q=max: probable flood discharge in cusecs

C=a co-efficient, which depends on the nature of the catchment, and the intensity of the rainfall.

M=catchment area in square miles.

2. The value of C as used in calculations varies from 50 to 2,000 in United Provinces. Possibly the range is even greater in some other provinces.

3. Sometimes different parts of the catchment are of different kinds, such as hills, or plains, cultivated or uncultivated, sandy or clayey, etc., and different values of C are to be used for each part of the catchment. In such cases some engineers calculate the flood discharge for each part separately from Dicken's formula, and then add together these flood discharges to obtain the flood discharge for the entire area.

4. This is not correct. The weighted average value of C should be calculated, and then the flood discharge for the whole area calculated with this value of C.

5. An example will make this clear. Suppose a catchment consists of two parts of 250 and 260 square miles, the values of C to be used being 1000 and 900 respectively, then

according to some engineers the flood discharge for the whole area $= 1000 \times (250)^{\frac{3}{4}} + 900 \times (260)^{\frac{3}{4}} = 1{,}21{,}000$ cusecs. If the value of C had been 1000 for the whole catchment the flood discharge would have been $1000 \times (510)^{\frac{3}{4}} = 1{,}07{,}500$ cusecs, which is less than the figure of 1,21,000 previously calculated even though the value of C is larger for part of the catchment. The figures for discharge given above are approximate, having been calculated by slide rule.

6. It is obvious that the calculation given above is wrong, and the writer would not have written this note if he had not found several responsible engineers making this mistake, but in view of the above he thinks that the note will serve some useful purpose.

7. In the above example the weighted average value of C comes to $\frac{250 \times 1000 + 260 \times 900}{510} = 949$, and with this value of C the flood discharge comes to

$949 \times (510)^{\frac{3}{4}} = 1{,}02{,}000$ cusecs, which is reasonable and correct.

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A.M.I.E.

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Note. Members are invited to comment on this note. T.S.

WORLD NEWS

OF

ENGINEERING INTEREST

Detection Devices for Incendiary Bombs.

The considerable attention now being given to defensive measures against incendiary bombs has led to the suggestion of special automatic fire detectors to supplement fire watching schemes, for it is not usually possible for the watcher to keep all parts of the building under observation at the same time. This subject is of such importance that the Ministry of Home Security has initiated certain experimental work to ascertain the capability of some systems of detection, and has set up an advisory committee of the Institution of Electrical Engineers which has now issued a Memorandum* on the subject. It is hoped that as the work is completed more detailed information will be published as British Standard Specifications.

Three general methods can be used to indicate the arrival of an incendiary bomb—(a) by the effect of impact ; (b) by the noise of impact ; and (c) by the light produced when the bomb ignites. Subsequent indications would be given by the fire or heat. Existing schemes for fire detection would detect the fire rather than the bomb itself although some such schemes could be suitably adapted. The detector can be arranged to initiate a suitable alarm or to operate fire fighting devices. The type of bomb considered in the memorandum is a 1 kg magnesium bomb which has a light output of about 6,000 candle power and a heat output of about 15,000 B.Th.U.

Impact Detectors.—One of the simplest impact detectors consists of two layers of wire netting separated by about 2 in. A falling bomb will cause the two layers to come in contact thus closing an alarm circuit. In one London building a strong hemp net is held under the roof on springs. Cords are also attached to the net and pass through metal eyes screwed to the wall, terminating in metal washers. When the cords are pulled by depressing the net, the washers will make contact with the eyes and cause the alarm to ring. Yet a third scheme

* Memorandum of the I.E.E. Advisory Committee on Fire Detection Devices, published by the Institution of Electrical Engineers. Price 6d.

employs a mesh on insulated wires connected in series. They are rigidly fixed to a crash board which ensures rupture of the circuit. They are arranged in units of convenient size with the wires spaced 6 in. apart.

These systems suffer from the disadvantage of requiring quantities of material—wire netting, for instance—which is urgently required for other purposes. The impact of a 1 kg bomb is of the order of 4,200 ft. lb.; after it has penetrated a roof it can only exert a small force on a further obstruction. These devices have to operate with fairly wide limits of impact energy. As such systems may be operated by falling debris the alarm should be an internal one and not automatically summon the fire brigade.

Light Detectors.—Systems operated by the light emitted, as soon as the bomb ignites, would at first sight seem likely to prove suitable for giving an immediate signal with a minimum of false alarms. These detectors consist essentially of one of the three main types of light sensitive cell ; namely, the selenium cell, the alkali metal cell and the rectifier cell, each of which must be considered separately.

The selenium (photo-conducting) cell consists of selenium deposited on a metal base and has the property that its resistance is decreased when it is exposed to light. In one well-known cell there are four electrodes arranged in the form of a bridge in such a way that variations in the polarising voltage are compensated for. This polarising voltage may be obtained from a battery or the supply mains, and the cell is used in association with an amplifier and relay. At least one bomb detection system using a selenium cell is in current production. It requires a sudden increase in illumination of 0·5 f.c. from darkness to operate the alarm. Unobstructed light from a 1 kg bomb would theoretically be sufficient to operate this device at a distance of 100 ft. A gradual increase in illumination would not cause operation.

In photo-electric cells of the photo-emissive alkali metal type the current through the cell is directly proportional to the illumination falling on the cathode. The sensitivity is increased by filling with inert gas but the linear relationship between illumination and current no longer holds. As the latter is unimportant, the increased sensitivity of a gasfilled cell can be utilised. Actual performance depends on several factors

including the amplifier and relay, but photo-electric detectors which operate on a minimum illumination of 0·2 f.c. are commercially available ; this corresponds to an incendiary bomb at a distance of 500 ft.

One system which employs this type of cell is arranged for either battery or mains operation, and in the latter case an alarm will be given if the supply fails. It is claimed that the ignition of a bomb 300 ft. from the detector will operate the alarm. This high sensitivity may place limitations on the detector, and it must be protected from bright lights. It may possibly be freed from these limitations by the use of suitable filters in which event the high sensitivity may be a necessity.

No detector system based on the use of rectifier cells appears to have been developed other than experimentally.

Fire Detectors.—Fire detectors may depend for their operation on smoke, heat or employ radio-active materials. Equipment of the first two classes is well-known. In some instances the necessary equipment is elaborate, and in others the alarm is not sounded until at least a modest fire has been started. Adaptions are, however, a possibility with a view to reducing these drawbacks.

The majority of fire detection systems depend on the effect of temperature. Devices more recently developed depend on the destruction of thin material by oxidation or flame. Systems using temperature as a basis make use of the expansion or melting of material, the most common employing thermostats. These may be arranged to operate when a predetermined temperature is reached or when a sudden rise in temperature is experienced. Thermostats of the first type usually operate at a temperature of 135-155° F., they therefore detect the fire resulting from the incendiary bomb rather than the bomb itself. For use specifically as a detector of the heat from the bomb either a very large number of thermostats are necessary or the settings must be appreciably reduced. This reduction can generally be easily arranged in commerical apparatus. Systems operating on rise in temperature usually require a rise of about 30°F. This type of thermostat could be designed to operate for a lower temperature rise, thus detecting a fire in the very early stages ; the risk of false alarms would, however, increase. Some systems based on the melting of materials have been specially designed for detecting incendiary bombs. One of these employs spring-loaded contacts separated by wax of low

melting point. A detector actuated by radiant heat is in course of development.

A combined detection system requires the area to be protected by parallel wires some of copper and some of tin. The alarm will, therefore, be given on the breaking of one of these wires, either by impact of the bomb or fusion of the tin.

There are several well-established systems for the detection of smoke in the early stages of a fire, and they are very certain and very sensitive in the detection of the fumes given off by a magnesium bomb. In these, the atmosphere of the space to be protected is continuously sampled by being drawn through small-bore tubes into a centralised cabinet. A beam of light shines across the tube and the presence of smoke cuts off the light from a light sensitive cell. Besides being expensive, however, these systems might give a false alarm in the presence of dust in the air caused by the explosion of a high explosive bomb nearby.

An interesting method of fire detection is that in which the conductivity of the air is compared with a known gas. The apparatus consists of two cylinders each having a central electrode. The internal surfaces of the cylinders are coated with a radioactive salt. One cylinder is sealed and contains a known gas and the other is to allow a continuous flow of air to be drawn through it. Any variation of the chemical composition or physical properties of the air (molecular charge of ionisation) will cause a change in the electrical characteristics of the open cell. This change is brought into evidence by a thermionic valve and amplifier. Practical knowledge of this system does not appear to exist in this country, but it is understood that the apparatus is in production on the Continent as a detector of incendiary bombs.

It is regretted that the report did not include advice on the actual installation of such systems and the siting of the detectors. However, the importance of maintenance is stressed, and all wiring should be properly installed and protected. There is an advantage in closed circuit systems since a defect in the wiring will operate the alarm. These systems and those using valve amplifiers require a continuous flow of current, so a mains supply is generally necessary, but a battery is also required as a standby.

Reprinted from the "Electrical Times", London, Feb. 20, 1941.

Concentrating Production.

The Government's suggestion to concentrate the production of certain industries in a reduced number of factories working on full time would have delighted the protagonists of rationalisation, of whom so much used to be heard a year or two ago. The very word rationalisation is what R. L. Stevenson called a boss word. There is also something comforting in the idea that all manufacturing effort is most efficiently carried out in large works. Nevertheless, no great reform is wholly good in its context any more than it is wholly bad. The point to be determined, therefore, is whether on the balance the good will outweigh the bad; in other words, whether, necessary as such a scheme may be in war-time, it may not ultimately lead to the permanent weakening of our industrial structure. Fortunately, we can examine this question with some detachment, since engineering is at present hardly affected by Mr. Lyttelton's proposals. What the Government has set out to do is to close about two-thirds of those factories in the country which are now engaged on non-vital production. The Limitation of Supplies Order has already restricted the activities of these factories ; and it is now considered that the reduced output can be more economically produced in a smaller number of factories working full time than in a larger number operating at one-third or less load. The factories that remain in production will manufacture not only for themselves, but for their suppressed competitors ; and the labour thus released will become available either for military service or for staffing new war factories. The buildings themselves, it is announced, will become available for storage and other purposes.

At present x factories, employing y men, succeed in producing z articles. If this production is to be maintained, will it be possible to employ fewer men and women if the number of factories is reduced to $x/3$. It is obvious that such concentration is possible, but the question is, will it be sufficient to free, as is anticipated, 500,000 to 750,000 employees for more essential work. To assist in answering this question, the results of an investigation into the food, drink and tobacco trades, contributed by Mr. G. H. Daniels to the Institute of Statistics in August, 1940, may be cited. He found that in July, 1939, 554,330 persons were employed in these industries. A reduction of output by 30 per cent would have released 33,260 persons, if it had been distributed over all the firms. By concentrating

production in the most efficient units, however, he calculated that no less than 202,340 workers could be released. These figures are admittedly estimates. Nevertheless, there is no reason to doubt their essential accuracy, since we may admit with the rationalists that more efficient equipment and better organisation permits the same production with fewer personnel. One other merit of the plan will be that it should cheapen production and thus obviate price increases to the consumer.

No objection can be raised to the proposals, therefore, on the score that they will not attain the object of releasing men and women for other purposes. There are other factors, however, which must be discussed, if only for the reason that, unless the scheme is to be permanent, ways of retreat to the conditions with which industrialists have long been familiar must be left open. Dealing with this point, Mr. Lyttleton has promised that the closed factories will be kept ready, so that they can be started up again as soon as possible after the war; and that the departments concerned will take all measures open to them to assist this speedy re-opening. Meanwhile, the Board of Trade is to keep a record of the factories closed down and the Ministry of Labour is similarly to schedule the transferred personnel, so that they may be able to resume their old employment after the war.

This, however, is not, and cannot be the whole story, for it takes no account of that illusive and intangible commodity, goodwill. It is around this difficulty that a great deal of criticism will centre; as indeed, it is doing already. Is it possible, in practice, it may be asked, to re-design the machine in the way suggested and then to reverse it when the time comes so that progress may once again be made along the old lines? Is it possible to shut down two out of three factories without adversely affecting the fortunes of their owners, and to restart them, after they have been closed for a period of months or more probably years, with no more trouble than is caused when they are shut down after the annual Wakes? Is it possible to hand over the production of goods to a competitor for a like period and then revert to competition once more without any shock to the system? This particular difficulty could be partially overcome, perhaps, by some scheme for the preservation of brands and trade marks. There has been no hint, however, as to whether this will be done and, if it were, complete protection would not be provided. For instance, assume the case where consumer A has always purchased the products of

manufacturer B, partly out of conservatism and partly because they fairly met his requirements. Under the new scheme, he is forced to purchase the products of manufacturer C, for they are the products of the latter, however they may be branded, and this knowledge cannot be concealed. A now finds, either that C's products suit him better than those of B or, at worst, that there is so little to choose between them that it makes no difference. When the war is over, conservatism will, therefore, once again tend to exert its influence, and make him stick to C as once he stuck to B. What then happens to B's business and how is he to be compensated for the harm which has inevitably been done him ? It is questions like these which will be asked when the approval, which always greets such spectacular proposals, begins to be tempered by consideration. It is no answer to say that "there is a war on."

In this connection, it must be remembered that at present the scheme, if not truly voluntary, will depend for its success in large measure on the co-operation it receives from the industry. Mr. Lyttleton has appealed for that co-operation and is looking to those concerned to effect the necessary measures of concentration in consultations with the Government departments. This is wise ; for it is obvious that the firms themselves are in the best position to frame plans in the light of their knowledge of their own capacity and circumstances. "Should," however, is not the same thing as "will"; and history shows that the reorganisation of an industry by voluntary efforts, when the interests of its members are unidentical, is by no means easy and may easily prove to be impossible. While, therefore, voluntary effort may well be given a chance, matters are too urgent to admit of long delay or of anything in the nature of filibustering. Compulsion cannot be kept too much in the background and must, if required, be applied without delay.

Fortunately, at the moment, it would seem that drastic steps will be unnecessary. On the day after he made his statement in the House of Commons, Mr. Lyttleton discussed the problem with representatives of the Federation of British Industries and meetings have been subsequently arranged with the employers in the pottery and other industries. In order to help the Board of Trade in carrying out its task, the scope of the Export Council is to be expanded and it will be renamed the Industrial and Export Council. A committee will be formed on which the Parliamentary Secretary for Raw Materials of the Ministry of Supply and a representative of the Ministry of Labour will sit.

The number of business members on the Council will also be increased with the sensible intention of ensuring that the industries concerned in carrying out the difficult task of re-organisation may be guided by men with experience of their problems. On paper, therefore, the prospects of the scheme are good, but everything will depend on how the difficulties that exist, and they are many, are tackled. Anything that would cause bad feeling and friction and still more hardship and injustice must be avoided. The Government have the powers to inaugurate this industrial revolution ; and no one will dispute their right to exercise them ; it is essential, however, that those powers should be exercised with discrimination and that nothing should be done which will render the return to more normal methods harder than it inevitably will be.

Reprinted from "The Engineering" London, March 14, 1941.

Engineering Institute of Canada.

* "...There are too many engineers with a narrow and petty attitude on these matters, mature men who complain, that the immediate bread-and-butter value of the researches and publications of a professional society are not worth the membership fee, and young men who complain because it does not serve them as an agency of collective bargaining. Shame on us! Do we look with envy on the high prestige of medicine and of surgery? Then let us not forget that this prestige has been won not merely through personal skill and service, but through magnificent contributions to human knowledge without profit to the seekers and with incalculable benefits for all mankind. Do we covet public leadership on a par with the legal profession? Then we do well to remember that the overplus which differentiates a profession from a technical vocation calls for personal development and for powers of expression sufficient to fit a man for a place of influence in his community.

"Measured by the standards I have been seeking to outline, many men who call themselves engineers and who are competent in accepted technical practices, can scarcely be said to have attained a real professional stature. These are

* Excerpts from an address delivered by Dr. Wm. E. Wickenden at the annual banquet of the Engineering Institute of Canada on 7th February, 1941.

the men who have let their scientific training slip away, who do not see beyond the immediate results of their work, who look on their jobs as an ordinary business relationship, who contribute nothing to advancement by individual or group effort and who have little or no influence in Society. They have been unable to surmount routine in the early stages of experience and have gradually grown content with mediocrity...

"I am encouraged by these trends to end on a note of prophecy. You are fighting a technological War and we are entering upon an all-out programme of technological defence in which every man under arms must be backed by more than a dozen in industry and in which only one man in four under arms is expected to carry a rifle. This experience is likely to have a profound effect on education. Within a decade we are likely to see technological education, both at the secondary and the higher levels, becoming more and more the dominant type.

"The climax of man's effort to subdue nature, shift labour from muscles to machines, to make material abundance available for all and to abolish poverty and disease, may well fall in the next 50 years. After that human interest may shift from work to leisure, from industry to art. Meanwhile engineers will multiply, research will expand, and industry will grow more scientific. Engineers will find their way into every field where science needs to be practically applied, cost counted, returns predicted and work organised systematically. They will be called upon to share the control of disease with physicians, the control of finance with bankers, the bearing of risk with underwriters, the organising of distribution with merchants and purchasing agents, the supplying of food with packers and purveyors, the raising of food with farmers and the operation of the home with housewives. In few of those new fields, if any, will engineers be self-sufficient; to be useful they must be team-workers; and they must be prepared to deal with 'men and their way,' no less than with 'things and their forces.'

"The engineering profession will exercise a far greater influence in civil and national affairs. It will probably never be able to define its boundaries precisely, nor become exclusively a legal cast nor fix a uniform code of educational qualifications...

"Engineering education must break away from its present conventional uniformity. At one extreme, a part of it must become more profoundly scientific; at the other extreme, a vast development of practical technical education for directing production will be in demand. Engineering schools ought to be less alike, less standardized by invitation...A science of human work needs to be created and systematically taught...."

Long-time study of Cement Performance in Concrete: Advisory Committee Appointed in America.

It is of concern alike to the producer and consumer of portland cement that the performance of concrete under the rigors of service cannot always be predicted or relied upon with certainty. These predictions are based upon premises which depend upon an attempted correlation of laboratory research and observation of field operations with field performance. Since the non-reliability of the predictions seems to be due to a lack of proper correlation between laboratory and field observations and field performance, the Portland Cement Association is about to undertake a long-time study of the performance of cement in concrete.

The programme to be followed in this study has been developed by an Advisory Committee comprising twelve members of which P.H. Bates is the Chairman. The committee has defined the objectives of the study to be the determination of, first, the extent to which the performance of concrete is affected by differences in cement, and, second, the factors responsible for such differences. Emphasis is to be placed on a study of the characteristics of the cement in relation to concrete performance, and variations in concreting methods and workmanship are, in general, to be avoided.

In the conduct of the study, field structures will be built by usual methods, but under close technical supervision, and the cements used will be representative of the whole range of commercially available products. These cements, during every stage of manufacture, will be subject to close scrutiny and exacting chemical and physical tests in order that the performance of the field structures as observed over a period of many years may be correlated with the characteristics of the cement. In the mill, complete records will be made of

all significant data bearing on the proportioning of raw materials, burning, cooling, and storing of the clinker, and grinding and storing of the cement. Adequate samples of both clinkers and cements will be taken to permit application of every known test for the determination of the factors sought, and a large quantity will be stored for use in any future tests that may be devised or seem desirable. In addition, samples will be made available to interested and properly qualified laboratories for co-operative studies.

The cements selected for these studies fall, in general, into five types, defined by the Tentative Specifications for Portland Cement (A.S.T.M. Designation : C150—40T) with an extra group to cover specially treated cements (ground with tallow, vinsol, resin, etc.). They will include representative cements of each type and those embodying various special characteristics, and attention will be given to the geographical distribution of the producing mills. In all, there will be 48 cements used, totalling approximately 35,000 bbl.

The field work will consist of ten major projects located in different parts of the country in order that a wide variety of conditions of soil, weather, and materials will be encountered. The cements to be observed, will be incorporated into concrete structures of several different types; a number will be full size structures, such as highway slabs, bridge decks and handrails, parapets, etc., which will undergo the usual loading and weathering encountered by such structures, and non-service test specimens, as slabs, piles, columns and box-type retaining wall sections.

Three of the principal projects will be experimental pavements constructed in co-operation with state highway departments under standard procedures in which cements representing the five standard types and the treated cements will be used. The pavements will be located in the north-east, south-east, and mid-west sections of the country.

Two projects, similar to the above and in conjunction with them, will study variations in consistency and exposure with treated and untreated cements.

Three projects will study effects of variations in fineness of cement, and in burning and cooling conditions of the clinker.

These experimental pavements will be private industrial road-ways where close control of materials and workmanship will be assured.

One project will be carried out at two locations where the effect of soils high in sodium sulphate and magnesium sulphate, respectively, may be studied. Regular and special cements will be used in concretes of three different cement contents.

One project will study the effect of fresh and sea waters on the six types of cement, using reinforced concrete piles of normal cross-section and lengths. Concretes of different cement contents and consistencies will be tried cut also. Exposure will be in the Hudson River, and in the oceans in Maine, Florida and California.

One project will feature the exposure of concretes containing the standard cements in thin sections in such structures as bridge decks, handrails, parapets, etc., to various conditions of frost and precipitation.

One project, using all the cements from the other projects, will study aggregates, mixes, and consistencies, in three types of specimens (slab, walls, columns), exposed to northern and southern climatic conditions on two experimental farms.

The scope of this programme, involving construction under close control, and observations over a period of years, of 90,000 sq. yds. of concrete pavement and an additional 2,500 cu. yds. of concrete in miscellaneous structures, should yield in the years to come a wealth of interesting and valuable information on many phases of cement and concrete technology.

Reprinted from the "Bulletin" of the American Society for Testing Materials, December, 1940.

Engineering Developments of 1940.

1940 was the year in which owing to war work American industry was given its greatest assignment—to help, intensively and quickly, in the National Defence Programme. To this opportunity there was an immediate and wholehearted response by the Army, Navy and Air Corps for a wide variety of technical products for direct armament, ranging from ship turbines to small airplane instruments.

Briefly these are enumerated as follows:

Electric drives for submarines, tugs, and mine layers; turbines for ship propulsion, delivering in some cases more than 50,000 horse power each; reduction gears up to 18 feet in diameter, weighing as much as 70,000 pounds, and machined to tolerances measured in ten-thousandths of an inch, through which these turbines are connected to the propeller shafts of naval vessels and merchant ships.

Electric and hydraulic devices for maintaining naval guns and searchlights at the desired position regardless of sea conditions, and instruments for indicating these positions at remote points; searchlights for anti-aircraft and other purposes, some of them five feet in diameter and delivering an 800,000,000 candlepower beam, by means of which an object 12 miles away may be illuminated under favourable atmospheric conditions; naval gun mounts and projectile hoists.

Radio transmitting and receiving apparatus; turbo-superchargers which permit airplanes to operate efficiently at high altitudes; electric generators of revolutionary design and greatly improved efficiency; propeller pitch control devices; gun-control equipment; and 75-mm. howitzers. Apart from the National Defence Programme conspicuous advances have also been made in Power Generation such as: High-pressure, High-temperature steam turbines and hydrogen-cooled generators. Double-frequency vibration has been practically eliminated in a 3600 r.p.m. generator by a resilient core mounting; in other designs such vibration was reduced by use of heavier cores.

The country's first 3600 r.p.m. ***quadruple-flow steam turbine-generator***, a 100,000 kW unit using 1250 lb, 950 deg. steam, went into service. Also in operation by the end of the year was the first of two 80,000 kW, single casing, single-flow turbines, largest of their kind in this country, using 1250 lb., 900 deg. steam and having hydrogen-cooled generators.

A mercury boiler having a single 54 in. drum replaced the original seven-drum boiler in the Kearny station of the Public Service Electric and Gas Co., New Jersey, occupying the same space as the earlier one. Increased operating efficiency has been attained.

Flue gas was used to drive turbines operating oil-refinery compressors, in one case the turbine being installed outdoors.

A 54,000 kVA vertical waterwheel generator was under construction for use with a reaction-type waterwheel to have an operating head of 925 feet, the highest-head waterwheel of such type.

Increased power, minimum voltage variation, and uniform potential distribution feature a constant-potential generator of new design built for the 1,400,000 volt x-ray equipment of the National Bureau of Standards.

Industrial Heating.—Drycolene, consisting of about 78 per cent nitrogen, 20 per cent carbon monoxide, and 2 per cent hydrogen, has been produced as a new protective atmosphere for heat-treating steel without decarburization.

Standard fluorescent lamps have been employed in a stroboscope developed for viewing cloth during processing, for checking register in cloth printing, or in discovering defects in cloth or printing process. Regardless of the speed of the cloth through the machine, a stationary cloth pattern is viewed.

An alnico magnet was made an important feature of a new glass coffee maker. The magnet turns the heating unit off automatically when the proper temperature is reached. A brow compensator makes it possible to prepare even small amounts of coffee satisfactorily.

A midget 100 watt floodlight—inexpensive, lightweight, and weatherproof—has been introduced.

General Electric Co., of Schenectady, U.S.A., have erected a permanent relay station for television station W2XB, in the Helderbergs south of Schenectady, for rebroadcasting New York City telecasts. It is the pioneer step in chain broadcasting of television programmes, considered essential in overcoming cost difficulties.

Steam-Electric Locomotive.

A steam-electric locomotive has been designed for the Union Pacific Railroad (U.S.A.) by the combined engineering skill of Messrs. Babcock & Wilcox, General Electric and Baily Meter Companies. The locomotive consists of two turbo-electric units each 90′ 10″ long. The boilers operate at a normal

pressure of 1500 lbs. gauge and are oil fired. The turbo-generators furnish energy for 12 D.C. motors which furnish a starting torque of 173,000 lbs. The total weight of the two units is 1,096,000 lbs. or approximately 500 tons.

The steam plant is a closed system containing less than 300 gallons of water and requires very little make up. The locomotive has been designed to haul a trailing load of 1000 tons for a distance of 2200 miles from Chicago to the Pacific Coast in 56 hours.

It is anticipated that the fuel costs will be slightly below those for a Diesel-electric engine and about 60 per cent of those of the reciprocating steam locomotive.

In spite of the great size, weight and capacity of present day locomotives, one would indeed be rash in predicting that the maximum has been reached.

The engineering genius of the next quarter of a century may produce examples of motive power in comparison with which the equipment of to-day will seem as out of date as do the locomotives of 1900 to-day.

The "Journal of the Engineering Association of Malaya", April 1941.

BOARD OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

New Research Schemes Sanctioned.*

Over fifty schemes of research were considered by the Board of Scientific and Industrial Research at their fifth meeting held in Simla, on May 16, 1941, and of these twelve were recommended. Of the latter, mention may be made of the following :

Manufacture of Carbon Electrodes for the Aluminium Industry, on which work is to be carried out at the Indian Institute of Science, Bangalore.

Application and standardisation of vegetable dyes from certain barks, to be carried out jointly by Mr. M. N. De at the Silk Industries at Bhagalpur and Dr. K. Venkataraman in the Department of Chemical Technology, University of Bombay.

Erection and operation of a pilot plant for the manufacture of butyl alcohol and acetone, by Dr. H. D. Sen and Dr. B. C. Guha at the Imperial Institute of Sugar Technology, Cawnpore.

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* The Technical Secretary will be glad to receive notes relating to advancement of Indian Industries.

Four schemes relative to synthetic dyestuffs were sanctioned. These concern the preparation of vat colours, by Dr. K. Venkataraman ; preparation of mono and di-alkyl anilines, by Mr. B. C. Roy, University College of Science, Calcutta ; investigation of electrolytic methods for the preparation of anilines, etc., by Dr. B. B. Dey, Presidency College, Madras ; and manufacture of aniline from cholorobenzene, by Dr. G. P. Kane, Department of Chemical Technology, University of Bombay.

The Board also recommended schemes for the continuation of work on the manufacture of vacuum and compressor pump by Prof. M. N. Saha, and for the manufacture of sodium cyanide, by Dr. J. C. Ghosh. The Board of Scientific and Industrial Research was created in April 1940 and it was not till the end of June 1940 that the scientific work of the Board was started and the Director of Scientific and Industrial Research was given the use of the laboratories of the Government Test House at Calcutta.

Reprinted from "The Indian Railway Gazette", June 1941.

Reference to Interesting Articles.

1. New WL Passenger Locomotive Service on N.W. Ry.—*Indian Railway Gazette*, May, 1941.

2. A Rational Method of Calculating the Lengths of Transitive Curves. —*Quarterly Technical Bulletin*, April, 1941.

3. Aircraft Structure—*The Structural Engineer*, January, 1941.

4. Moment Distribution & the Analysis of a Continuous Truss of Varying Depths—*The Engineering Journal of the Engineering Institution of Canada*, February, 1941.

5. Design of R.C. External Columns Made Easy—*Indian Concrete Journal*, May, 1941.

6. Some Aspects of Surveying in Indian Coal Mines.—Transactions of the Mining, Geological & Metallurgical Institute of India, March, 1941.

7. Fundamental Application of Soil Mechanics to Piled Foundations—*Journal of the Engineering Association of Malaya*, April, 1941.

8. Discussions on the Stability of Buildings under Bombardment—*Journal of the Engineering Association of Malaya*, April, 1941.

9. Steam Turbine Electric Locos—*Indian & Eastern Engineer*, May, 1941.

10. Reinforced Concrete for Sanitary Engineer—*Bulletin of the Institution of Sanitary Engineers*, April, 1941.

11. Some Fresh Aspects of Trunk Road Design—*Roads & Road Construction*, April, 1941.

12. Measurement of Wind Velocities with the Kata Thermometer—*The Electrical Times*, London, March 27th, 1941.

13. Progress in the Detection of defective rails—*Journal of the Western Society of Engineers*, U.S.A.

14. Standardisation of fixed arched Bridge design in Reinforced Concrete —*The Structural Engineer*, London, April, 1941.

Following research publications* issued by the National Bureau of Standards, Washington D. C., U. S. A. may be of special interest to our members.

Ref.		*Price.*
BMS 1	Research on building materials and structures for use in low cost housing by H.L. Dryden 5 p. ...	10 C
BMS 7	Water permeability of masonry walls by C. C. Fishburn & Co. 35 p. 7 illus. ...	10 C
BMS 17	Sound insulation of wall & floor constructions by V. L. Chrisler 33 p. 43 illus. ...	10 C
BMS 32	Structural properties of 2 brick concrete-block wall constructions & a concrete-block wall construction H.L. Whellemore & Co. 19 p. 34 illus. ...	10 C
BMS 34	Performance test of floor covering for use in low cost housing by P. A. Sigler & Co. Part 1, 14 p. 20 illus. ...	10 C
BMS 43	,, ,, Part 2, 20 p. 37 illus. ...	10 C
BMS 44	Surface treatment of steel prior to painting by R. E. Pollard & Co. 17 p. 9 illus. ...	10 C
BMS 52	Effect of ceiling insulation upon summer comfort by T.D. Pillips (in press).	
M 112	Manufacture of insulating board from cornstalks by O.R. Sweeney. 29 p. 10 illus. ...	10 C
M 123	The production of pressboard from cornstalks by B. Wingfills & Co. 10 p. 2 illus. ...	5 C
M 125	Directory of commercial test and college research Laboratories by H.E. Rapuzzi. 55 p. ...	15 C
M 140	A study of deterioration of book papers in libraries. A. E. Kumberley—etc. 9 p. ...	5 C
M 147	Paper making quality of cornstalks by C.G. Weber & Co. 9 p. ...	5 C
M 151	Design & construction of building exits 79 p. 19 illus. ...	10 C

*Available from the Superintendent of documents, Washington D. C., U. S. A. at prices stated.

THE CENTRAL IRRIGATION & HYDRODYNAMIC RESEARCH STATION

AT

KHADAKVASLA, POONA.

During the 21st Annual Session of the Institution of Engineers (India) in Poona last January 1941, arrangements * were made to visit the Research Station, where demonstration of various models was shown to the members. As the visit proved of considerable technical value, a description of these models is included in this Journal to form a useful technical record for our members.

The Central Irrigation and Hydrodynamic Research Station originated over 20 years ago in the Special Irrigation Division under the Government of Bombay. In 1937 it was taken over by the Government of India to serve the whole of India.

Its functions are to give advice and carry out model experiments in connection with river training and hydrodynamical problems concerning canals and irrigation.

Following models were selected for demonstration.

(1) ***Gibb Modules***: The Gibb Module was designed by Mr. A. S. Gibb of the Punjab in 1909 and is a device to give a constant discharge, irrespective of the water levels upstream and downstream, within its working range.

The advantages of Gibb Modules are :—

(i) The discharge remains constant even though the water level upstream or downstream varies.

(ii) It has no moving part, is simple and cannot get out of order.

(iii) Silt or other solid matter in the water does not affect its action.

(iv) It requires no attention.

* Mr. P. E. Golvala, the then Hon. Secretary of the Institution of Engineers (India) organized this visit.

A general formula for Gibb type modules was worked out at this Station, and many experiments were conducted to ascertain the best design for various conditions. The three modules which are kept for demonstration at the Station have the ratios of $\frac{\text{outer radius}}{\text{inner radius}}$ of the eddy chamber = 1·8 ; 2·0 and 2·2. Of these the module with a ratio of 2·0 gives constant discharge for the maximum range of water levels. Water is led through a circular pipe and then through a rising pipe having a circular section at the inlet and a section giving free vortex flow at the other end before it enters the eddy chamber. The excess head is dissipated in the eddy chamber by baffles, which skim off excess top water, throw it up into one of the vortex compartments where further energy is dissipated and finally it falls down on the water below thus dissipating still further energy.

(2) ***Model of the Nara River and Head of Mithrao and Khipro Canals (Sind)***: The Mithrao Canal derives its supply from the Eastern Nara above the Makhi Regulator ; and the Western Nara, which also supplies water to the Jamrao Canal, some miles upstream and the Hiral and other Canals downstream, was previously a river which drew its supplies from the Indus at Sukkur. Now it is fed from the Eastern Nara Canal from above the Sukkur Barrage. Owing to scour in the Nara, coarser silt than previously drawn, began to enter the Mithrao in 1932 and the previous drop into the canal of 2′6″ at full supply discharge gradually disappeared, so that command was lost.

Experiments were therefore carried out to find out how to exclude silt from the Mithrao Canal and the best solution was found to be a separate approach channel for the Mithrao from concave bend upstream.

It was recommended that the old river bed should be partly re-opened to carry water to the Makhi Regulator and Khipro Canal ; the existing straight channel after reduction in width being used as an approach channel to the Mithrao Canal. This lay-out was such that the approach channel took off where the beneficial effect of curvature was a maximum so that only top water containing only fine silt entered the Mithrao approach channel, the heavy bed sand being deflected into the river downstream.

This recommendation was acted on and "command" was at once restored and the drop into the Mithrao at the Head Regulator gradually increased to 1′ 6″.

The problem was again referred to this Station in November 1940, this time to see how silting of the Nara River downstream of the Makhi Regulator could be reduced. This could be done by increasing silt draw into the Mithrao Canal, which was permissible to some extent owing to the effectiveness of the realignment previously recommended and adopted. Two alternatives were suggested:

(i) to create turbulence upstream of the approach channel by constructing short groynes pointing 45° downstream, the groynes being fixed about 1,000 ft. upstream of the nose ; this would throw bed silt in suspension, which would then be drawn by the Mithrao, or

(ii) to close the approach channel and to draw water for the Mithrao through a cut made in the Nara River.

(3) *Siphon Spillway for the Jamshedpur Water Supply*: Instead of an open spillway, siphon spillway is proposed, as this would reduce flood lift and increase the storage. This particular design to 1-10th scale gives a high co-efficient of discharge (*viz.* 0·73) and also gives an equivalent priming depth of only about 6 miles due to a water seal caused by a high co-efficient weir downstream. These results compare very favourably with the Indore type siphon, which has a baby siphon to cause early priming (1 ft.) ; the co-efficient of the latter is 0·51 for the same upstream depth over the sill of the siphon (*viz.* D=1·5 ft.). Pressures are observed in the model, from which the design of reinforced concrete shells can be worked out.

(4) ***Experiments to Test Design of Nose of the Outer Bank of Proposed Right Bank Approach Channel above Sukkur Barrage***: The layout of the proposed approach channel above the Sukkur Barrage may be seen in the model of the Barrage at the other side of the Station.

In this model, which includes a part width of river only, and is "geometrically similar" (*i.e.* without vertical exaggeration), the object is to test the stability of the nose of the approach channel. The bank consists of sand with loose stone protection. When scour takes place in the river and the bed becomes deeper, the stone "launches" downwards, extending the protection to the toe.

(5) ***Standing Wave Flume*** : This is a device for measuring the discharge of water in small channels or large canals, and has many advantages over the alternative methods of gauging with floats or weirs :

(1) Accuracy within 3 per cent.

(2) Gauges can be fixed to give a direct and immediate reading, which can easily be checked.

(3) Simple in design and little to get out of order. Cannot be tampered with.

(4) Moderately cheap to construct, and no maintenance cost.

(5) Causes little afflux (*i.e.* raising of upstream water level).

(6) ***Experiments with High Co-efficient Weirs—Full scale model*** : It is of great advantage in certain cases of weirs *e.g.* waste weirs of reservoirs, to be able to discharge a large quantity of water with a small depth over the crest, as then the crest may be set at a higher level without raising the maximum flood level in the reservoir above the safe limit, and the higher crest level permits a larger quantity of water to be stored.

By means of model experiments a weir profile has been evolved which has a higher co-efficient. *i.e.* is able to pass more discharge for a given depth, than any weir yet constructed. Models of 3 different scales have been tested, to observe the effect of scale in addition to the model shown, which is of full-scale. The length of weir in the particular case for which this design was evolved (Lake Arthur Hill, Bombay Presidency) was about 600 ft.; owing however to the high rate of discharge per ft. run, only 4 ft. could be represented in this model, requiring a discharge of 130 cusecs. Special methods were used to correct the results for side-wall effect, involving the use of 2 small scale models of the full-scale model. The side-contractions upstream are required to stabilise the flow and ensure even distribution of discharge.

(7) ***Training the Sarda at Banbassa and Preventing Scour Downstream of the Barrage—U. P.*** : This is a boulder river, the maximum size of boulders being 18 inches. There are

two spurs, the Burma and Nepal spurs projecting from the left bank, and one short spur to protect the Right Afflux Bund. The Sarda River has three approach channels.

The changes in the river course showed the necessity of both banks being groyned, for the control of the River, within a width of not more than the length of the Barrage.

Experiments are now being carried out with a geometrically similar part width model of the two left bank bays of the Barrage to prevent scour downstream of the pavement, which sustains damage during floods.

(8) ***Control of Silt Entering the Right Bank Canals Taking off Above the Lloyd Barrage at Sukkur (Sind)*** : As a result of a slight bend upstream of the Sukkur Barrage, the left bank canals, which are on the concave bank, draw little bed silt, but the right bank canals, being on the inside of a curve, draw excess bed silt.

The object of the experiments is to test various alternative designs to reduce and control silt draw by the right bank canals and, in particular, the north-west canal.

In 1935 only a small amount of silt entered the canal. The amount of silt entering in subsequent years up to 1938 increased in quantity, and though considerable scour occurred each October, which brought down the silted bed level to the order of 1 foot, the canal lower down gradually deteriorated. Conditions got so bad by 1939 that a large expenditure had to be incurred on silt clearance of the canal and right pocket. In an effort to reduce silting, a policy of 2 day closures of the right bank canals, combined with undersluice scour was adopted and a change of regulation of the barrage, mainly a change from semi-open flow to still-pond in the left pocket, was adopted. During the 1939 Abkalani, the river moved to the left bank upstream of the gorge and translated more towards the right bank between the gorge and the barrage, and downstream of the barrage. The net result of all these changes was a reduction of the silt wave in the north-western canal during the Abkalani. As to whether this was partly due to the new approach channel outer bank, which was under construction from November 1939, cannot be judged.

The solution recommended was to construct an approach channel, starting 5,000 ft. upstream of the barrage from which

the supply for the canals would be drawn off over a raised silt at a point 2250 ft. above the barrage, the rest of the water and most of the bed silt flowing on down the tail channel and through spans 15 to 22 of the barrage.

This particular investigation required the use of 5 models with different vertical exaggeration

viz *nil* (*i.e.*, geometrically similar model)
= 2·0
= 3·0
= 5·0
= 7·5

to see the scale effect on curvature of flow.

(9) ***Remodelling the Sone Anicut at Dehri (Bihar)*** : The anicut is 12,448 ft. long. During floods water is escaped over the crest throughout its whole length. To facilitate scouring, 20 falling sluice gates were provided on each bank and 16 sluice gates in the centre of the anicut, but being inaccessible in floods, the latter have never been operated. Over the remaining length falling crest shutters were provided.

The anicut feeds two main canals, one on each bank.

As the leakage through the shutters over the anicut is considerable and as the present arrangement for scouring is inadequate, it is proposed to raise the crest of the anicut permanently by 3 ft., and to operate all the sluices electrically to scour away silted bed during floods.

Experiments are required

(i) to determine the shape of a high co-efficient weir which will not cause afflux,

(ii) to determine lengths of permanently raised weir crest,

(iii) to determine the length of Divide Walls,

(iv) to consider how to improve silt exclusion from Canals, so that they need not be shut except during peak flood conditions as against up to 30 days during the flood season as at present,

(v) to design the necessary downstream protection to prevent damage to the structure.

The present model is a part model including the central sluices with a length of weir on both sides and experiments regarding (v) are being done. Experiments regarding (i) are being conducted separately in geometrically similar models.

(10) ***The Calibration Channel and Measuring Tank*** **:** The calibration channel is arranged so that a measuring device or other hydraulic structure to be calibrated can be tested against volumetric measurement in the measuring tank. A 2 ft. Crump type standing wave flume is at present constructed to determine the effect of velocity of approach on the discharge formula. The channel is provided with instantaneous deflecting device so that, water which is flowing with hypercritical velocity to prevent back pressure, can be diverted into the measuring tank or to waste, without affecting the flow in the channel in any way.

The measuring tank, constructed in reinforced concrete, is 20 ft. in diameter and 25 ft. deep (capacity of tank = 6,000 cu. ft., sufficient to measure 20 cusecs for 5 minutes).

(11) ***Sand Channel*** **:** Channels flowing in sand or silt form their own shape and size in cross-section. Experiments are being carried out to find the stable size and shape of cross-section, using various grades of sand and different discharges. The present experiment is being done with local Red Silt.

(12) ***Falls of Various Designs. Experiments with Different Designs of Canal Falls for a Discharge of 700 Cusecs*** **:** Three falls have been constructed on the Pakpattan link of the Haveli Project (Punjab) at R.D. 35,500 ; R.D. 37,500 and R.D. 40,284. The first was designed by Mr. A. M. R. Montagu for a drop of 6·63 ft., fluming ratio = 1·43 ; the second by the Central Irrigation & Hydrodynamic Research Station, Poona, according to their standard, proportional flume-meter fall design for a drop of 6·63 ft., and fluming ratio = 2·5 and the third by the Central Designs' Office, Punjab, for a drop of 6·82 ft., fluming ratio = 1·43.

Experiments were carried out with geometrically similar models with the above three designs.

***Conclusions* :** It has been obvious for some time that no single design of fall would be best for all conditions ; for instance, it is recognised that for low heads and small discharges per foot run, a vertical fall gives sufficiently satisfactory results and is cheap ; but wavewash is considerable so this type of fall causes unsightly bank scour where discharge intensity is high or fall more than about 4 ft. It is also less suitable than flumed falls where the fall is combined with a bridge, and particularly so when combined with a regulator.

Again a fall which is suitable for designed conditions, may give trouble should retrogression occur. For this reason, it was fortunate that the Poona design was adopted for the Tando Mastikhan Fall on the Rohri Canal, Sind.

All these falls gave satisfactory results ; but Montagu's design gave the best result and it seems clear that for discharges up to say 1,000 cusecs his design is best ; but for larger falls or higher discharges per foot run, the Poona design has definite advantages, even as regards cost. These advantages increase with size.

(13) *1/500 Scale Model of the Ganges above the Hardinge Bridge (Eastern Bengal Railway)* : Total length of the model is 550 ft., equivalent to 40 miles upstream and 12 miles downstream.

The Hardinge Bridge, which is about a mile long, and carries the main line of the Eastern Bengal Railway from Calcutta to the North, was constructed in 1915. The site was carefully chosen having regard to the stability of the river course. To safeguard the bridge against lateral movement of the river, Bell bunds—long guide banks pitched with stones, were constructed for a length of 3100 ft. upstream of the bridge and for 100 ft. downstream—to control the direction of the current. At that time, the main current was along the left bank of the river at the Bridge. Gradually, however, it changed its course to the right bank ; when, owing to the concentration of flow, deep scour occurred, being as much as 200 ft. in one place, *i.e.* 150 ft. below Mean Sea Level. Early on the morning of 26th September 1933, on a rising river following heavy rains during the previous week, the flow along the Right Guide Bank became so intense that the bank breached and the gap rapidly widened. The attack was so severe that the fate of the whole bridge, which had costed about

£3,000,000 to construct hung in the balance. Train loads of stone were heaped around the embayment and the disaster temporarily averted, pending more permanent protection works ; but various protection works had cost over £1,000,000 during the previous 2 years and the attack still continued. A committee was therefore appointed in August 1934 to decide what action should be taken, and it was agreed that the Railway Board should ask the Khadakvasla Research Station to carry out research to determine the cause of failure and to ascertain how to ensure the future safety of the bridge.

The probable cause of the trouble and how to meet it, was outlined and model experiments were then carried out at this Station to test the soundness of the diagnosis and proposed remedies. It was found that the Damukdia guide bank —which was built a year prior to the disaster to guide the high velocity flow through the centre of the Bridge made flow conditions worse and increased the intensity of diving flow at the Right Guide Bank, which then failed. The final recommendation was made to remove the stones of the Sara Guide Bank and allow it to scour naturally, so that the high velocity flow instead of being deflected towards the Damukdia Guide Bank would fan out naturally towards the Bridge with reduced turbulence. This was acted on after the floods of 1935 and the projection of the Sara bank which was the cause of the trouble is being gradually scoured away. The Damukdia channel which cuts across straight towards the Bridge carried only some 8 per cent of the discharge during floods when conditions were at their worst. This is now carrying 25 per cent and will now increase until it becomes the main stream, which will eliminate from attack the Lalpur Bight above Sara for some 25 years or more.

(14) ***Tidal Model of the River Hooghly*** : Erosion of the river bank has occurred at the Dunbar Mills and lower down at the Titaghur Jute Mills near Calcutta. The model represents 22·5 miles of river from Bansbaria upstream to Konnagar downstream, the horizontal scale being 17·6 ft. to the mile. This reach of the river is tidal, Konnagar being 44 miles from the sea approximately, and in the model special methods are required to reproduce the tides. The river discharge enters the model at the upstream end while a constant discharge of 2 cusecs is led to the downstream end and introduced there to represent the tidal "flow." The

tidal "ebb" is produced by escaping discharge from the downstream chamber through a needle valve actuated by means of relay system by a cam revolved by clockwork. Cams of different shapes will be used to reproduce the tidal ebb and flow of the various seasons. At the upstream end of the model is a "labyrinth" required for the absorption of the tidal flow passing out of the model proper, as there is a considerable length of river within the tidal range above Bansbaria, the upstream limit of the model.

(15) ***Training the Jumna River at Delhi*** : The Delhi Gate Pumping and Power Stations were constructed on the Right Bank of the River in 1922 when the river course was along that bank. The river subsequently moved across to the Left Bank below the Railway Bridge, crossing to the Right Bank again only downstream of the Pumping Station, so that in order to obtain access to water when the river is low, cuts have to be made each year across the silt banks. The river is held firmly on the Right Bank upstream of the Bridge by masonry works constructed along the bank, and on the Left Bank downstream of the Bridge by groynes.

In 1937, the question of bringing the Jumna across from the left bank to the Delhi Gate Pumping Station on the opposite bank was referred to this Station. Experiments with 1/200 scale V.E. model carried out in this connection have been dealt with in the last 3 years' Annual Reports.

Pitching of stone crates was recommended along the face of the river at the Pumping Station in 1938. At the end of 1938, a bye channel was opened along this face of pitched bank and at the end of 1939 flood, the main channel cut across to the Pumping Station ; but has again gone back to the old course after 1940 floods. Both the 1939 and 1940 were low flood years (flood discharge less than 40,000 cusecs), as against 1933, when maximum flood Q = 105,408 cusecs and 1924 (Q = 205,182 cusecs). A large 1/120 scale V.E. model is now constructed to see the scale effect and to investigate methods to bring the river to the pumping station under all conditions of flood discharges.

The Twenty-First Annual Dinner.

The Twenty-First Annual Dinner was held at the Poona Club Ltd., on Friday, 31st January 1941. The Chief Guest was Sir Ardeshir Dalal, Kt., I.C.S. (Rtd.), Director, Tata Iron and Steel Co., Ltd. 93 members with 57 guests, including 19 ladies, were present.

The President proposed the toast of His Majesty the King-Emperor.

In proposing the toast of Sir Ardeshir Dalal, the President said :

Sir Ardeshir, Ladies and Gentlemen,

When I was asked by the Secretary of the Institution of Engineers (India), on behalf of the Council, to agree to be nominated for the Presidential Chair for the year 1940-41, I was told that in case I was elected I would have to preside over the annual general meeting and the annual dinner to be held at Nagpur (C.P.) which is included in the Bombay Centre of the Institution. I was afterwards informed that the venue of the meeting would be shifted from Nagpur to Poona and perhaps from Poona to Calcutta due to the outbreak of Plague at Poona. I am glad that to-night's dinner which is the Twenty-First annual dinner of the Institution is being held at Poona. This is for two reasons—firstly I find myself in a homely atmosphere being surrounded on the one hand by the members of my own fraternity and on the other by friend-guests instead of stranger-guests, and secondly I am not a stranger to you, Sir, who are the chief guest of honour of to-night's function. I had the good fortune of working with you for some time when you were the Municipal Commissioner for the City of Bombay and you know me well and are already well aware of my short comings. It was you, who were instrumental in making me leave the Indian Service of Railway Engineers by securing a post for me in the Bombay Corporation about eleven years ago. I think that this is the most fitting occasion when I should publicly thank you, Sir, for having given me an opportunity of serving the citizens of Bombay.

Ladies and Gentlemen, you all know Sir Ardeshir was one of the most distinguished and brilliant members of the most coveted and celebrated Service—the I.C.S.—from which he retired before superannuation to take the role of an industrialist, which he is fulfilling so efficiently and eminently as the Director of the Tata Iron & Steel Co. His Presidential Address before the 28th session of the Indian Science Congress delivered in the early part of this very month shows the marked progress made by the Steel Industry, on which we, Engineers, are largely dependent for our work.

There is a close and intimate relationship between Engineering and Industry and the material prosperity of our country is dependent upon the co-operation between the two. The progress of engineering in any country is a gauge of the progress of civilisation. As civilisation advances, so must engineering. It is the engineer's job to build up, beautify and improve the material conditions of humanity. With the advance of civilisation the engineer's work is becoming more intimately connected with and more dependent on those who labour—on the one hand in the realms of pure science and on the other in the pursuits of commerce, finance and politics. It is therefore fitting that Sir Ardeshir, who is a vital force in such an important industry, should be the chief guest of honour of our Institution to-night. I hope that his presence here to-night would result in securing closer co-operation between Industry and Engineering and thus help in promoting further material progress in our country. It is my pleasant duty and privilege therefore, on behalf of the members of the Institution of Engineers (India), to accord you, Sir, a most cordial welcome and to offer you our grateful thanks for honouring us by your presence at to-night's dinner. We are sorry to miss Lady Dalal, but I can assure you, Sir, that our joy would have been doubled if she could have graced this function by her presence.

Ladies and Gentlemen, before I perform the most pleasant duty of proposing the toast of the chief guest of honour, I would like to digress a little by making a few general remarks about the affairs of our Institution. The Institution has this year attained majority. It was founded 21 years ago in 1919 and His Excellency Lord Chelmsford had honoured the inaugural meeting with his presence. The headquarters of the Institution are at Calcutta in its own building, the foundation stone

of which was laid by His Excellency Lord Irwin (now Lord Halifax) and the opening ceremony was performed by His Excellency Lord Willingdon in 1931. Through the efforts of the past Presidents and the Members of the Council the Institution was granted the Royal Charter in 1935. This is the only Institution in India which has the privilege of a Royal Charter. The Institution has seven local centres, *viz*. Bengal, Bombay, Hyderabad (Deccan), Mysore, North-West India, South India and U.P. They are so situated that they cover the whole of India. There is also one more centre outside India in London. Our membership to-day stands at 1472. This strength does not compare favourable with the number of qualified Engineers practising in India, but we hope to increase our strength by inducing them to join our ranks by making them realise that their enlistment would be very useful for the material benefit of the country in which they earn their livelihood apart from the personal advantage they would derive from the Corporate Membership of the Institution. We have managed to maintain a high standard in the profession but to-day our chief problem is to provide increased facilities for adequate practical training of young engineers in their student days so that there might be openings for them in industry and private enterprise. The industrial prosperity of India will depend upon her ability to obtain a sufficient number of well-trained men to serve in industrial concerns and the adequate training of these men is possible only with the whole-hearted co-operation of industrial concerns. In this connection I can very appropriately refer to the remarks made by Mr. Christie, in his Presidential Address to the American Society of Mechanical Engineers. He stated "America looks to our young engineers for future development. They must have the best training possible. The Colleges are doing a creditable job. It is the industries who are responsible to complete the post-graduate training of our young mechanical engineers in a better manner than heretofore."

You, Sir, have been very good to the Engineering profession inasmuch as you take up for training at Jamshedpur young Engineers without any premium, but other industrial concerns have not yet seen their way to do so. We can only succeed in making good engineers in this country if we were to pay more attention to their training during the undergraduate and the post-graduate years. I have already spoken this morning regarding co-operative system of education

followed for the training of engineers in America and such training in this country also would be possible only with the help of the Industries.

I would like to speak about one more very urgent need of the profession before I formally propose the toast. It is about the importance of research in the Engineering Industry. Research is the soul of every industry and it is of as much importance in the Engineering Industry as in any other. Every engineer is indebted to his predecessors in the profession for the information that makes it possible for him to design and construct efficient structures. Each project, large or small, owes its success to the adoption of methods that have been developed on the previous ones. It is always a process of evolution. We build on the foundations which have been made possible for us by our predecessors. The engineer can repay this obligation by securing and making available to others the additional knowledge that is being developed in his practice. In India, this aspect of one's duty has been sadly neglected, and due to this we have to use the experience and data available from work done in Western countries. The science of engineering as practised in Western countries in regard to certain branches such as road making, water supply, sewerage and sewage disposal, building materials, etc. is based upon local conditions obtained in those countries which conditions not being identical with those obtaining in India, the practice cannot be followed in this country without some modifications. To evolve data and conditions suitable for any particular locality, it is necessary to make small scale experiments and this can be done only by the co-operation of the industries by financing research organisations. In Western countries, industries finance research either by having a Research Department of their own or by several sister industries co-operating for maintaining one research organisation, and in many cases half the cost of the co-operative research organisations is borne by Government. The experience of the industries in the Western countries in the financing of research has been so good that the industries who either started research organisations or had taken part in co-operative effort have never had the occasion to regret the same. Research has not only paid for itself but has always added greater profits in the Balance Sheet. But if we study the history and the origin of research organisation in Western countries we find that in a majority

of cases the research organisations came into existence on account of Government initiative. Most of the research organisations which we find in existence in England to-day are due to the activities and initiation from the Department of Scientific and Industrial Research which came into existence as a result of the last Great War. It was only when the Government showed the way and made the industries realise that research paid not only for itself but actually paid dividends that more and more industries began to take part in the co-operative system of financing research. We have now in India a Department—Board of Scientific and Industrial Research—started by Government somewhat on the lines of the Department of Scientific and Industrial Research in England. This as all of you know has come into existence on account of the urgent problems connected with the present War and I would like to stress the fact that in this Department greater stress is given to the problems connected with chemical and physical aspects of Science. If we are to make any headway in the Engineering Industry, greater attention to research in engineering industries will have to be paid. It is no doubt true that certain firms have made efforts in this direction and we are happy to have amongst us to-day Sir Ardeshir Dalal who represents the House of Tatas, a firm which has been a pioneer in the sponsoring of technical research. In the field of research activity the name of Jamshedji Nasserwanji Tata, the founder of the Tata concerns, will always be gratefully remembered for his foresightedness in establishing the Science Institute at Bangalore. To facilitate research work in Metallurgy, a modern well-equipped Laboratory was erected in 1937 at a cost of over Rs. 10 lakhs at Jamshedpur by Tata Iron & Steel Company. Encouraging and useful as these individual efforts are, great strides in this direction can only be possible if one can persuade and influence the Government to give single-minded support for the furtherance of engineering research in this country, and I am sure that we can have no better representative than Sir Ardeshir Dalal to use his good offices and influence in bringing prominently to the notice of the Government of India the necessity and desirability of establishing and encouraging research work in engineering.

Ladies and Gentlemen, you are aware that as an engineer I am not accustomed to making long speeches and I know that you are very anxious to hear the reply of the chief guest of

honour. I therefore now ask you to fill your glasses and drink to the health, happiness and long life of our chief guest of honour; Sir Ardeshir Dalal.

Sir Ardeshir Dalal responded as follows :—

Mr. President, Ladies and Gentlemen,—I am very grateful to you for the honour you have conferred upon me by inviting me as your guest at this annual function of your Institution and for the more than kind words in which you have proposed the toast of my health. In your own words, Mr. President, I have had the good fortune to work with you in the Bombay Municipality and you know me well and are already well aware of my shortcomings, although you have carefully refrained from making any reference to them in your speech. If I have been in any way instrumental in securing your services for the Bombay Municipality, I am gratified that, by doing so, I have rendered a service to the City of Bombay, as the record of your work since then has amply proved.

Though not an engineer, my lot has been cast among engineers for a very long time now, in fact ever since 1926-1927, when I was Financial Adviser to the Sukkur Barrage and the Bombay Development Department. The Steel Company employs hundreds of engineers, with whom I come in daily contact. You have dwelt upon the necessity of securing closer co-operation between industry and engineering in order to promote the material progress of our country. The necessity of such co-operation has been stressed on many occasions in the past, but at no time was it so urgent and imperative as it is to-day. You owe the very existence of your Institution to the circumstances created by the last war and the necessity it disclosed for more vital co-operation between industry and engineering, which led to the appointment of the Industrial Commission and to the recommendation of that Commission to form the Institution of Engineers. But even the last Great War was by no means so entirely a conflict between the industrial potentialities of the warring peoples as is the present War. It is the engineer assisted by the scientist who designs the instruments of destruction as well as defence, which the industrialist manufactures and the fighting man utilises. For many a year after the war the services of the engineer will be required for the task of repairing the ravages of the war and rebuilding a new world. In India, although we have so far

happily escaped the destruction and havoc which have been wrought in other theatres of war, we have our own problems no less urgent and no less important. During the war we have to render the utmost assistance that we can to pursue it to a victorious conclusion. After the war we shall have our problems of reconstruction as well as development. The war has disclosed serious chinks in our industrial armour. Although some progress in industrialisation has been made since the last war as for instance in iron and steel, sugar, cement and some of the engineering industries, we are still in a position to-day in which we cannot manufacture a single internal combustion engine or a locomotive or an aeroplane or an automobile. We are, therefore, unable to take the part in the War or in the defence of our own country which the size and importance of India requires. Since the start of the War, further progress has been made. Munition factories have been largely expanded. A number of things which were not previously produced in the country, are being produced. Three or four plants for the manufacture of basic chemicals have been or are being put up and the manufacture of aluminium is being projected by two different companies. Plans have also been made for the starting of an aircraft factory and a ship-building yard. But a very great deal still remains to be done. Progress is hampered for want of machinery and machine tools.

Another great difficulty that is being experienced is in securing the requisite trained men. The training of the engineer as a practical man has principally to be carried out in the workshop. Very few colleges or other teaching institutions have got the equipment for the necessary practical training. You, Sir, have rightly stressed the importance of such training and the duty that lies upon the industrialist in helping to secure it. As many of you may be aware, in the Tata Iron & Steel Company we have a scheme for the training of our superior employees in a Technical Institute of our own. We select the required number of apprentices from among graduates in mechanical or electrical engineering or metallurgy and train them in our Technical Institute as well as our works for a period of two years, during which we pay them stipends. At the end of the period, if they are qualified, they are employed in various capacities in our plant. Apart from that, we have a scheme for the training of our lower grade employees, under which about eighty-five young men are

taken up every year and put through a five years' course of training, during which they get small stipends until they are employed in subordinate capacities in our plant. Besides that we have night schools for the training of our adult workmen. We also used to admit boys from engineering institutions for short periods of training, but since the war we have had to stop the practice. So great, in my opinion, is the necessity for practical training of engineering students that I think that there should be an organised scheme of such training, under which not only all properly equipped industrial concerns but also Government factories, and railways and municipal workshops should be made to admit a certain number of students for practical training. It is upto your Institution to devise some such scheme and put it up to the authorities concerned.

You have also dwelt upon the importance of research in the engineering industry. My views on research were expressed at some length in my recent address to the Indian Science Congress at Benares. The newly established Board of Scientific and Industrial Research has made a promising beginning and has already accomplished some useful work. Its attention, however, would for the present be mainly confined to researches in Physics, Chemistry and in our mineral and fuel resources. Valuable research in irrigation engineering is being carried out by the Public Works Department. As for roads, a research scheme financed from the Road Fund appears to be very suitable.

Your Institution has just attained its majority. I wish it a long and prosperous life during which it may continue to render valuable services to the engineering profession as well as to the country.

Mr. S. B. Joshi in proposing the toast of "Our Guests" said:—

Sir Ardeshir, Mr. President, Ladies and Gentlemen,—It is my pleasant duty to-night to propose the toast of "Our Guests". I had once thought that a prohibitionist like myself is ill-fitted for this task. I only reconciled myself in the knowledge that some prohibitionists can get drunk without drinking.

It will be asked whether the present is an opportune time for functions like this when one of the most devastating wars is being fought across the seas. The history of the last eight

months will provide the answer. The Battle of Britain was won by the fine morale of the British Public who refused to get panicky and give up their daily routine.

We engineers must play our part in fair as well as foul weather. We are not afraid of cyclones, earthquakes, floods as well as of wars. Our only prayer is that our statesmen do give us due notice of the wars, they want to fight and win, as the meteorologists give us notice of the disasters to come.

We have with us to-night Dr. Normand, Director of the Meteorological Observatory. He brings us floods, cyclones, earthquakes and timely rainfalls too ! The engineer's task would be greatly handicapped, if he had not the co-operation of this Messenger of the God of Weather! We are thus deeply interested in the prosperity of Dr. and Mrs. Normand and are thankful to them for having established contact with us.

We are sorry that the Presidents of the Poona Municipality and Poona Suburban Municipality are not here to-night on account of peremptory urgent duties elsewhere.

It is very inspiring to have with us to-night so eminent an Educationist as Principal Jog of the Wadia College. He represents the spirit behind the educational institutions in Poona. Indeed Poona leads the whole of the province of Bombay in its educational activities. Somebody told me that Principal Jog was a Parsi! How could he otherwise run an Institution with the aid of Parsis. He is not a Parsi. He only proves that communalism does not come in the way of a good cause, and especially so with the Parsis. I wish Principal Jog were one of our own members to persuade the Parsis to be kind to us and to provide us with the funds, we are so much in need of.

We are thankful to Principal Patel of the Agricultural College and Mrs. Patel for having accepted our invitation.

I have a long list of engineers amongst our guests and wonder if there is any mistake. How can engineers be guests of engineers ? We are greatly honoured by the presence here to-night of Lieutenant-Colonel Adlard, Commander, Royal Engineers, Poona and Mrs. Adlard. Without exaggeration he is busy for all the twenty-four hours with his multifarious and urgent duties. I am sure he comes here not merely as a guest but in response to an inner call to duty, that an engineer must meet and confer with an engineer. We are also deeply

indebted to Mr. Wylie, Superintendent, Ammunition Factory (modernization), Major Baxall, Superintendent, Ammunition Factory and Mrs. Baxall for their company to-night. It is no secret that 50 per cent credit for the success of this year's session goes to the visit that we are permitted to pay to the Ammunition Factory to-morrow. I can assure all these engineers in the Military Department, that we of the Institution are ready and willing to do our duty in these critical times. We are waiting for our turn. Those also serve who only wait and see.

Coming nearer home I cannot think of Mr. R.G. Sule, Superintending Engineer, Deccan Circle, P.W.D., and Principal Taraporewala in terms of "Our Guests." I know by personal experience that Mr. Sule takes keen interest in this Institution and is always willing to help us. So is the case with Principal Taraporewala. May I suggest that there is a limit beyond which modesty ceases to be a virtue! They should early seek entrance into our folds.

I must make special mention of the Ladies who have graced this function by their presence. Ladies and engineers have some things in common. Ladies' Bills are as perplexing to their husbands as engineers' budgets to the administrators.

We are deeply thankful to all other guests whose names are not specifically mentioned. We are also thankful to the Press and trust that they will extend the same courtesy to us as hitherto before.

I ask you now formally to raise your glasses to "Our Guests".

In response to the toast of "Our Guests," Dr. C. W. B. Normand, Director-General of Observatories, said:—

Mr. President, Ladies and Gentlemen, I wish that an abler speaker than myself had been called upon to reply on behalf of your guests. It may be that you wanted someone outside the engineering profession, and one who can speak from another angle. As a meteorologist I have a good deal of interest in engineering. There has been a close association between engineers and meteorologists and it goes back to ancient days. Indeed I submit to you that the first meteorologist was also the first great engineer. His name was Noah. He made a forecast of heavy rain. He predicted a deluge.

Now, in those olden days, just as now, the people took little heed of the meteorological warnings; and they paid the penalty. But Noah had faith in his forecast. He was the first enthusiast for A.R.P. He took Anti-Rain Precautions. He builded himself a great ship, larger (if you believe the scriptural tale) than any ship built by any other engineer in the next few thousand years.

Noah had combined meteorology and engineering within himself and made a success of it. The next association of engineers and meteorologists, that the legendary stories tell us about, was not so successful. You will recall that they planned a mighty tower to study the upper air. But it was so great a work that it was necessary to gather labour from all the ends of the earth and the multitude of languages and tongues ended in confusion and in the chaos of the Tower of Babel, not unlike to-day.

Sir, we meteorologists envy you, the engineers. You seem to have the more satisfying job. You plan, you build and finally you see with your own eyes the completed structure. You harness the forces of Nature to your will. You train rivers to go where you decide they should go. When you are dissatisfied with the weather that the meteorologist provides, you air-condition it. You make it hotter or colder, damper or drier, as required. You have your feet firmly planted on the earth while we work with our heads in the clouds. We have to be content to observe, record and study the forces of nature. We stand meekly by and watch the cyclone and thunderbolt strike where they will. These natural forces of course sometimes get the better of the engineer too. I am reminded of the story of an engineer who was out on a survey. He was camping on a farm. One boisterous stormy day the farmer was surprised to see him drop from the clouds down into the next field. The farmer said "You are an extraordinarily plucky man to come down on a parachute on a day like this." The engineer replied with a tremor in his voice. "But I didn't come down in a parachute. I went up with my tent."

Forces of nature that defy the engineer and the meteorologist are incentives to the amateur and the quack. The amateurs send you and me bright ideas as to how best to induce rain out of unwilling clouds. Some tell us to fire cannon at them. So the Libyan desert ought to be one of the rainiest

spots on earth just now. Others say we must sprinkle chemicals from aeroplanes. Farmers in America in recent years have actually paid "rainmakers" thousands of dollars to produce rain. A dozen years ago there were some fifty private forecasters in the U.S.A. publishing and accepting money for worthless forecasts, mostly based on methods no better than the American almanac of 1870 which said that when you see 13 geese walking Indian file with their toes in, you can bet your bottom dollar on a hard winter.

Well, the engineer doesn't worry himself about rain-making. He's content to be a rain-catcher. It's not for nothing that the engineering profession has attracted lots of Scotsmen. You grab the rain where it falls. You store it and then lead it by waterways, canals and pipes to where it is wanted. That is likely to remain the cheapest and the only effective way of controlling rain-water for many a long day to come. And I, as a meteorologist, hope you will build more and larger reservoirs and storage tanks. When I go to golf in the monsoon over the Bund Bridge here, it is rather a heart-break to see so much precious rain-water running uselessly to the sea without producing electric power or conferring other benefits on its way. It does seem to be a shortsighted financial policy that demands an early or even a direct return on such fundamental undertakings.

Sir, on behalf of all your guests to-night, I thank Mr. Joshi for the kindly but rather flattering words in which he proposed the toast and we thank the members of the Institution of Engineers here for the way you honoured the toast and for your hospitality.

Principal J. A. Taraporewala of the College of Engineering in proposing the toast of "The Institution" said:—

Mr. President, Ladies and Gentlemen:—When your Secretary invited my wife and myself to this very enjoyable function I thought I was to have a treat, though I knew there was some snag somewhere. My suspicions were confirmed when about two days ago I was asked by your worthy Hon. Secretary to raise the toast of your Institution.

I feel very much like the man who was called upon to sing at a similar function when he was blessed neither with the voice nor the technique of singing. He acceded to the request and at the end of his performance he was called by an

old crony sitting at the back. "I say" said he, "you did your very best, I know you did, but if you tell me the name of the fellow who asked you to sing, I'd wring his neck." So if I fail in the attempt, Ladies and Gentlemen, you'll know whose neck you'd want to wring!

Thinking of your Institution one naturally thinks of other similar Institutions in other parts of the world. I was trying to find a means of measuring your stature vis-a-vis with other Institutions. It seems to me that an ideal institution must fulfil the following five functions —

(1). That it must encourage and advance the Science of Engineering.

(2). That it must become the guardian and protector of the interests of the profession in relation to the public.

(3). That it should enforce a high standard of engineering education and practical experience before honouring an individual with its membership.

(4). That it should enforce a high standard of ethics in the profession.

(5). That it should form sound traditions of internal management of its Councils.

Taking the first function permit me to ask you if you are doing enough. There are heaps of engineering works of interest being carried out in the country. Have you called upon those responsible to submit papers thereon for the information and guidance of other members of the profession? It is sufficiently realized by those who are honoured by the membership of your Institution that they owe a duty to the Institution by disseminating what they know and execute to other less fortunate members of the profession? It is a pity that a number of efficacious remedies have been lost in our country by the most unfortunate habit of the person knowing them to keep them secret.

Coming to the standards of education, permit me to ask you if they are pitched high enough for your membership. Can I be elected to your membership? If the answer is yes, I am afraid your standards are not high enough!

There is a lot to be done in improving the ethics of the profession. You must wield the same power as the Medical Council over Doctors. By wielding such power it would be possible to expose the black sheep of the profession and what is more the lay public would realize that they would always get a fair deal from the Engineering Profession.

I mentioned about sound traditions of internal management. You may, in your complacency, think that the internal management of your Institution is your own business. May I remind you that the prestige of your Institution and the power it is going to be in the land, are entirely dependent on the type of men in your ruling Councils. Have you made provision to see that only men of position, responsibility and worth are allowed to get within the holy precincts of your inner Councils? Canvassing for votes has lowered the prestige of many a public body by throwing wide open the doors of entry to a lot of third raters. Men of position and worth dare not stand, particularly in a professional institution like yours, the dust and din of canvassed elections. No Chief Engineer would dare to stand for election, when he knows he would be swamped by the lesser lights by the simple process of canvassing.

Your Institution has well-known names on its rolls, names of men known even outside the boundaries of our own country. Greatness therefore is inherent in the mere existence of your Institution. You have merely to retain your greatness. It is a pleasure to see around here to-night men in flesh and blood—men who have been responsible in changing the very surface of Hyderabad, Mysore, Travancore, men who are recognized as authorities in irrigation in the Deccan and the Punjab, men who are experts in Town-planning, Municipal Engineering, in Power Station work, in Mechanical Engineering, in its multifarious branches and so on.

May your Institution progress more and more; may it act as a guardian and protector of all interests of the Profession and may it have an existence, worthy and honourable, for all time to come! Now, Ladies and Gentlemen, pray drink with me the toast of "The Institution."

Mr. J. D. Daruvala responded as follows:—

Mr. President, Ladies and Gentlemen, I deem it a privilege to respond to the toast of "The Institution" so well proposed

by my friend Principal Taraporewala and the manner in which you, Ladies and Gentlemen, have so enthusiastically responded to the same.

Let me, to start with, dispel from the mind of the proposer any apprehension that may be lurking in his mind that it was a preconceived thought to burden him with the task of proposing to the toast of "The Institution" that the inviiation was extended to him. It was only last week that the Hon. Secretary had seen me and requested me to suggest a name as to who should be entrusted with the toast of "The Institution" and after discussion we came to the conclusion that a man who was at the helm of affairs of an Engineering College would be the best person to propose such a toast. Principal Taraporewala has touched some important points which concern our Institution very vitally. As regards his reference to encourage and advance the science of Engineering let me assure you that the science of Engineering is encouraged and during the last year the Bombay Centre held 14 Paper and Lecture Meetings at which the Corporate members and Students of the Institution had taken a keen interest and deliberated upon important engineering questions which were discussed at such meetings. Referring to the interests of the profession in relation to the public I may mention, without disclosing any secret, that only this afternoon the Council had considered the question of the Act for the Registration of Engineers in India and have entrusted the same to its Sub-Committee. This is of course an important question which cannot be decided offhand and must receive at the hands of the Council consideration and care which is necessary before finally recommending it to the Government for enacting a law for the Registration of Engineers ; but it may be taken for granted that the matter is receiving the earnest attention of the Council and we hope that in the very near future a tangible proposal will emanate from them.

Reference has also been made regarding the ethics of the profession. May I enquire if such ethics could be enforced unless there is legislation to support the working of the same ? We hope that with the enactment of the Act for Registration of Engineers it may be more convenient for this Institution to enforce more rigidly the ethics of the Profession than it can do at present. Many of you may be aware that this Institution is the only body which holds the Royal Charter and this honour had been conferred only about 5 years back. There can be no

apprehension so far as membership of the Institution is concerned as every application that is received for admission, particularly for Corporate membership, receives the strictest scrutiny of the members of the Local Centres as well as of the Council and I am confident that if we continue to dispose of the applications which we receive in the manner in which we have been doing, particularly during the last three or four years, the membership of the Institution will be looked upon as a hall-mark for any engineer worthy of the name.

May I in conclusion refer to the next question which pertain to young engineers, viz. the reduced starting salary of engineers both in the Provincial Governments and Local Bodies and may I take this opportunity to make a personal appeal to Principal Taraporewala and Mr. Sule, Superintending Engineer, Deccan Irrigation Circle, who have graced the banqueting table to-night, to see that every endeavour is made to uphold the interests of the profession and I also earnestly appeal to all the engineers present to-night to resist to the utmost any endeavour made in that direction which might lower the position and honour of young engineers, who should begin their life on an adequate salary and remuneration. Repercussions of low paid staff are obvious and if the profession were to start with the meagre salary, then a time would soon come when the students seeking admission to Engineering Colleges would not be of the calibre as at present. I, therefore, earnestly appeal that this question should be looked into, not only by the Council of the Institution but those responsible for the revision of grades.

With these words, Ladies and Gentlemen, I thank you once again for responding to the toast of "The Institution."

V. GANESHA IYER, Esq., M. I. Mech. E.
Chairman, Mysore Centre.

LOCAL CENTRES

V. GANESHA IYER[1], **M. I. Mech. E.**

Chairman, Mysore Centre

****Gentlemen:***—I am deeply thankful to the members of the Committee of the Institution of Engineers (India), Mysore Centre, for the honour they have done me in electing me Chairman for the ensuing year. I have been a member of the Committee ever since the Local Centre was formed. I shall do my best to deserve the confidence you have placed in me.

Before I proceed further I wish to say how great has been our loss in Mysore by the passing away in quick succession of the late Yuvaraja His Highness Sir Sri Kanthiraya Narasimharaja Wadiyar and the late Maharaja His Highness Sir Sri Krishnarajendra Wadiyar Bahadur, G.C.S.I., G.B.E. During the long and beneficent reign of 38 years of His Highness the late Maharaja, the State made such rapid progress in all directions—Finance, Education, Engineering, Public Health, Maternity and Medical Aid, Chemical, Agricultural, Cottage and Engineering Industries, Architecture, Town Planning, etc., that to-day Mysore leads the rest of India in Industries, Civic Improvement and Economic prosperity.

We offer our most loyal devotion to the person and throne of his illustrious successor His Highness Sri Jayachamaraja Wadiyar Bahadur. May His Highness have a very long and prosperous reign.

We greatly miss to-day Rajakaryaprasakta Diwan Bahadur the late N. N. Ayyangar, who in his various capacities as Chairman and Committee Member had helped to promote the growth of this Institution so long.

I shall not inflict any long speech on you especially as I find that much that is good, great and useful has already been said before and has also appeared in the papers recently.

1. Mysore Service of Engineers (Retd.)

* Presidential Address, read at the 6th Annual General Meeting.

I shall however allude to some points which deserve special emphasis because of their importance and perhaps dwell a a little longer on one or two others.

I should refer first to Research Work which is necessary in every branch of engineering in order to make progress easier, smoother and more rapid. In matters of engineering we have merely remained as pundits hitherto, receiving and interpreting the rules and formulae which the West have had to give us, whether drawn from the accumulated experience, traditional skill, or high mathematical reasoning. I do admit we have many large works to our credit in civil engineering—roads, bridges, dams, irrigation, canals, buildings and railways. Our accumulated knowledge must lead us on to greater perception of scientific principles underlying, and simplification of details. The Hydro-dynamic Research Station at Poona, and the Research Station in the Punjab have done much original work. But these are only few. For this vast country, we must have many more of them. We should try and contribute as liberally as other nations are doing to enrich the world's stock of engineering knowledge. One of our foremost problems to-day in Mysore is the silting up of tanks and reservoirs; another equally important is the the economic use of irrigation water, prevention of water logging and spread of malaria.

The successful adaptation of Reinforced Concrete Work to suit all conditions and climates, and the elimination of the dust nuisance to pedestrians on roads caused by fast motor traffic without much cost are also deserving of attention. The prevention of the annual inundation of rivers in the deltaic regions causing great loss of life and property is one of the most serious problems baffling the civil engineers to-day.

I wish also to enquire whether the last word has been said and whether the existing system of providing flood escapes for tanks and reservoirs by means of open weirs and lift gates cannot be improved upon. These have got their own advantages and disadvantages. Flexibility of control is a great point in favour of lift gates. Open weirs, having no mechanical parts to get out of order, are never failing and are therefore fool-proof. Automatic gates and siphon spillways have been put forward as partial alternatives but they have not gained favour with the engineers so far. In our own small experience, siphons of the type used in the

Marconahalli Reservoir offer the great advantage of disposing of the floods in the main river bed itself, indicating that a separate waste-weir is perhaps unnecessary. The solution probably lies in a judicious combination of some of these alternatives. Further experiments and research are however necessary. The working of the waste-weir siphons at Marconahalli has left no doubts in our minds that by constructing simple siphons over the body walls of waste-weirs considerable additions to storages of existing tanks could be made without either raising the bunds or endangering their safety. The siphons act promptly and effectively in the disposal of the floods.

In Mechanical and Electrical Engineering, we have in India, barely a few Iron and Steel Works and Hydro Electric Power Stations; but in regard to their manufacturing side, we are on the very threshold yet. There are no undertakings in the country of any magnitude for building machines, machine tools, boilers, locomotives, electric motors, generators, transformers, steam and hydraulic turbines. The necessary materials are not available in the country; and engineering graduates and technicians are either unemployed or engaged in mere maintenance work. They are hungering for opportunities for designing and building, and doing research work. It is some satisfaction that in the field of pure science India is making some headway. It is up to us engineers, also, to reach similar high standard of thinking to purpose and come into line with leaders of thought in the West.

Fortunately we have in India to-day a galaxy of engineers capable of holding their own and therefore there is every hope that not in the distant future they will become bright stars in the firmament. Some say that it is unnecessary for us to spend money and do research. "Let others do the research for us. Whatever good comes out of it we shall adopt it straightway. There is nothing lost in remaining a few years behind other nations." "I do not know if you acquiesce in this view. Arguing on these lines we should soon go back to the dark ages again. No, instead of being helplessly dragged behind in this manner like lumber, we should quicken ourselves up and try and march abreast of the times. The discoveries of scientific research lead to greater improvements in the technique and ultimately to better living; and taking a distant view, they gradually unfold to us

the design on which this vast universe is broad based, bringing us materially nearer and nearer to God.

Gentlemen, you all know this is a vast country with resources in men and material practically untapped yet. All the same the number of men unemployed is growing day by day. Agriculture cannot absorb them; there are no vacancies in Government service. Industrial concerns are only a few. Trade requires both capital and experience. The struggle for existence is therefore becoming increasingly acute, and the necessity for starting new industries and exploiting the mineral wealth of the country doubly imminent. These larger industries can only be started with the backing of Government, in the earlier stages at any rate. The history of almost every new enterprise is the same. In this connection you will have noticed that in his address delivered on the 16th of December last to the Mysore Chamber of Commerce, Sir M. Visvesvaraya has made forceful plea for Government support in order to achieve "Rapid Industrial Advance", without which we should perish.

To us engineers of all denominations a tremendous amount of work is ahead and until we accomplish this we cannot take rank with the progressive nations of the world in regard to production and self-sufficiency. We have not only got to acquire the necessary skill and ability for making various kinds of machinery needed for transport, for power generation by steam, oil, gas and water, and also machinery for agriculture, textiles, automobiles, ship-building, etc., but we have to start using them; likewise the making and using of heavy chemicals, dyes, synthetic resins, artificial silk, leather, watches, meters, precision instruments, telephones, radio sets and a number of other items. The manufacture of aluminium for which there is scope in the country and also urgent need should be speeded up forthwith. Imagine what a time lag all this has meant for us and when we are in a fair way towards developing the above industries what a vista of opportunities for employment for all our men.

When I look on the amount of work that is before us, and the several decades that separate us from others, I feel that we must effect a drastic cut on our musical and other entertainment hours, recreation and sleep, and redouble the hours of work in order to make up for lost time. Immediately after the last war, one morning as I was going round a

factory in Germany, I learnt that the hours of work were suddenly raised from 8 to 10, without any corresponding increase in wages. I expected there would be a strike. There was nothing of the kind. The workmen took the change coolly and simply said that they had to work harder, because they had lost the war. There is much in this simple statement. There is patience, patriotism and to my mind, practical philosophy. After all there is no gainsaying the fact that work is the philosophy of life; there is real comfort in work and service for the country.

The Government of India have recently been pleased to accord their approval to the starting of an aeroplane factory in India, and a company with Rs. 4 crores capital has since been floated in Bangalore. The Government have also accorded their approval to a ship building industry in Vizag. Both these are major industries, and though many of the component items have to be imported for the present, yet in due course several subsidiary industries will spring up and supply many of the requirements. Incidentally I may mention that Navigation on modern lines with charts and instruments is a sealed book to us so far. We do not know what it is to design and build harbours and steam ships. With the advent of ship building I hope we shall one day be able to pass through the Panama Canal by, shall I say, S.S. "Karnatak" under our own command.

The Manufacture of automobiles is likewise an industry of the first rate importance, and if the Government of India, would help to usher in this also, we should be entering on a new era of large industrial expansion, Many industries ancillary to this will come in its wake such as the manufacture of alloy steels, aluminium, rubber, glass, paints, varnishes, non-ferrous castings, nickel chrome and cadmium plating, ball bearings, etc., let alone the great impetus to mechanical skill, invention and craftsmanship. The country will literally be humming with production, banishing poverty and unemployment—an end devoutly to be wished.

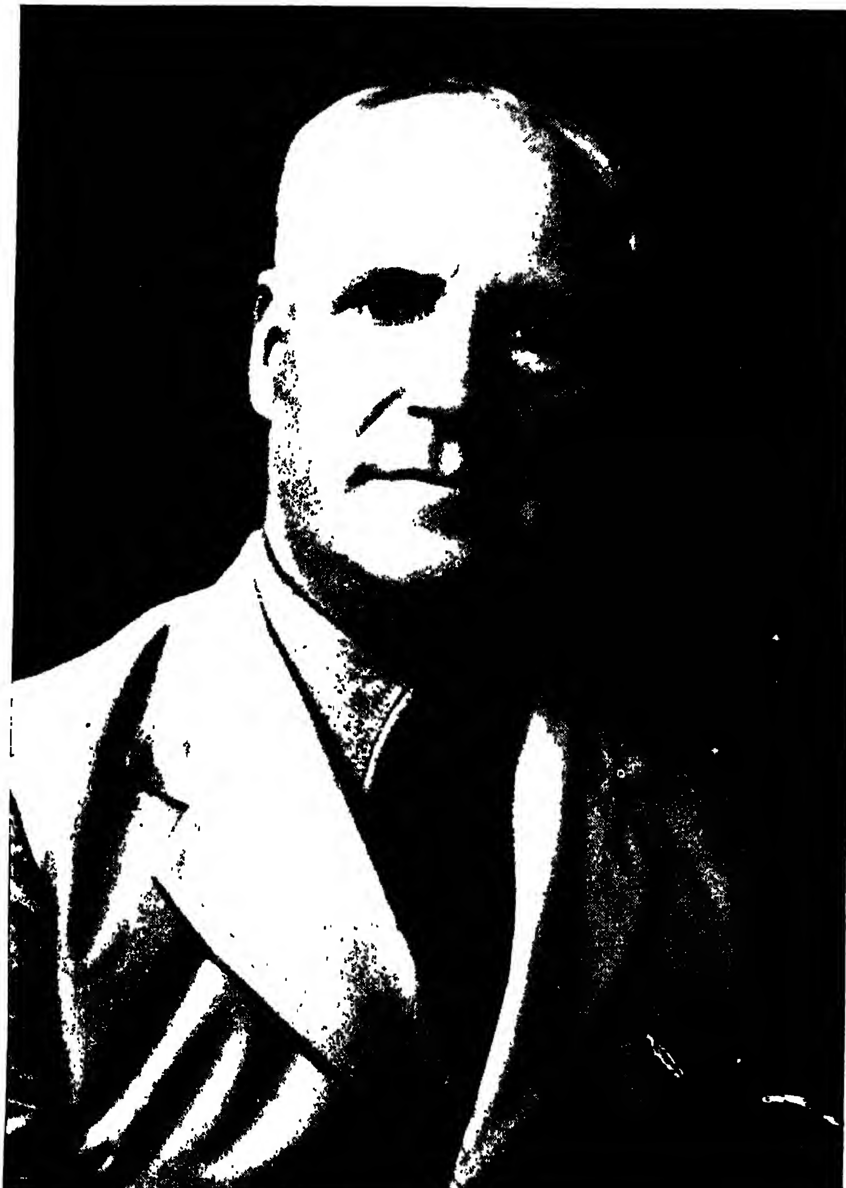
Gentlemen, I have taken a most cursory view of the situation of the country. It is enough to show that the engineer is intimately associated with almost every aspect of its industrial and economic progress, and his brain and brawn are both needed for their make-up. You have unlimited opportunities before you, and you have merely to bestir yourselves and seize them.

While almost all the amenities of civic life are created by the engineer, and the wealth of the country is in a very generous measure due to the sweat of his brow, there is a widespread feeling amongst the engineers all the world over that they are mere "drudges of the national household" and they have no part or lot in the governance of the country and in shaping its industrial and economic policies. Perhaps, the engineer is too much pre-occupied with his own constructive work, and he does not find time to interest himself actively in other walks of public life. The doctor and the school master are possibly of the same frame of mind. A plausible explanation is that the minds of these men are already biased and move in a groove and cannot view public questions with a balanced mind. Fortunately we have to our credit engineers of great vision and courage who have not only been an ornament to the profession, but have adorned with rare distinction the chairs of statesman and administrators. In various ways they have given an unmistakable lead to the country in its onward march towards peace and prosperity, such men are however few and far between.

In a lesser way it has been within the competence of professional men to attract attention and get their existence recognised by the public by coming to the fore on occasions and speaking on subjects of topical interest, and also frequently contributing thought provoking articles to newspapers and periodicals. A few of these also have become legislators and administrators. Nevertheless, there is a vast majority of engineers of high mark, gifted with sound commonsense and clear perception, who by virtue of their frequent exercise of patient thinking and steady working, can fill most worthily any high appointment of Government calling for those qualities.

It is a pity that in most cases after retirement many eminent engineers having no hobbies of their own practically allow their talents to go to waste. It is necessary that they form associations of specialists and continue to take a live interest in their professional work and raise the level of Engineering knowledge in the country. The mobilisation of their valuable experience and brain power is imperative in the interest of national economy.

Gentlemen, I thank you very much for your kind indulgence in listening to me.



F. C. GRIFFIN, Esq., M.Inst.C.E.
Chairman, North-West India Centre.

F. C. GRIFFIN[1], *M. Inst. C.E.*, *M.I.E.*
Chairman, N.-W. I. Centre.

**Gentlemen :*—First of all I must thank you for electing me as your Chairman for the ensuing year. Our Institution lives in its Branches, and the North-West India Centre is by no means the smallest of the Branches. The office of Chairman carries with it considerable responsibilities, and these I shall do my best to discharge. About 9 years ago I had the honour of being elected Chairman of the Bengal Centre. But it is no less an honour to be Chairman of the North-West India Centre. It may be a fact that our big brother, the Bengal Centre, possess the largest membership and also the Institution head-quarters buildings, but that need not daunt us in our endeavours to make the North-West India Centre a great success. Neither need we be daunted by the difficulties under which we labour. Our membership is 169, and our meeting place is here in Delhi. But only about 30 of our members are actually resident in Delhi, and some of those perhaps come under the classification, "Delhi-Simla". Consequently, we can scarcely expect large attendances at our ordinary meetings. Nevertheless, if we pull together, we shall be able to make our Centre really interesting and useful.

I would like to make an appeal to all engineers in Delhi who are qualified to do so, to join our Institution and give it their help. These Institutions are not normally things out of which we get something, though doubtless in our younger days membership is a great help towards advancement. Normally the Institution is a means through which we can work for the betterment of our fellow men and the country in which we live. If all the Delhi engineers would join up, our position would be immensely strengthened.

We have met together here in the midst of a world war of devastating intensity. In that our lot is cast in a land, which, up to the present, has not been involved in actual fighting, we are indeed fortunate—doubly fortunate. Some in my hearing may yet be called to active service. But with all of us the thought must be constantly in mind as to what we can do to help in the common cause of democracy and liberty. Let us at all events do our duty—not only our duty, but a little more than our ordinary duty, in the work which comes to our hands.

1. Suptdg Engineer, Health Services, New Delhi
* Presidential address read at the 14th Annual General Meeting held in Delhi on 22nd Feb , 1941

I believe it is usual for a Chairman in his opening address to refer to the particular line of engineering in which he is engaged. Since coming to India in 1913, and for four years before that, I have concentrated on water supply, surface drainage, sewerage, and other works included in the category of sanitary engineering. Domestic water supply alone is a big subject, and our Institution in the course of its history has published a number of excellent papers with regard to it. But I do not propose to touch on that subject to-day, although I might say that the Waterworks with which I have the honour to be connected at present (Delhi) is a fine bit of engineering and is well worth close study. I want to take you on to sewage disposal, and my excuse for referring again to a subject on which I said something at a meeting a short time ago is not only the importance of the subject, but the fact that it is a line of engineering in which there is a great scope. I mean scope for further advance, invention, and development. It is one of the newest lines of engineering, and yet, in a sense, perhaps the oldest. We talk of "modern sanitation", although there is evidence of there having been sewers and rudimentary types of water closets in the ancient cities of India. But the proper purification of large volumes of sewage is an up-to-date engineering matter, and it so happens that we have in Delhi the largest sewage works in India, dealing completely and effectively with the whole of the sewage of its 500,000 population.

Not many years ago the only methods of dealing with sewage were either broad irrigation, or settling tanks and filters, the latter being either trickling filters or contact filters. Some 20 years ago however, the activated sludge process came into being, and we now have different methods of applying this process, the principal ones being the diffused air system and the simplex system. In the last 2 or 3 years the trickling filter has been brought back in another form, the "enclosed filter". The utility of this in India is now being tested at Bombay, where an enclosed filter 78 feet in diameter and 12 feet in depth has just been constructed at the Dadar Works.

The Delhi Sewage Disposal Works was fully described by my predecessor, Mr. J. A. R. Bromage, in his paper published by the Institution of Civil Engineers in April 1940. The discussion on the paper was very interesting, and finally, by correspondence, some of us here have given complete information on the up-to-date working of the plant, the latter appearing in the October 1940 issue of the Institution Journal. I now

want to say a few words about the products of the Sewage Works. The plant takes in crude sewage, and delivers three products,—purified effluent water, eminently suitable for irrigation ; dried sludge useful as manure ; and, power gas. It is to the general interest of the public that effective use is made of these products so that their value comes back to the public. Since the installation of proper sewage purification works has only recently begun in India, the matter of utilization of products is important in connection with future developments.

1. The effluent water.—We can now claim that Delhi is demonstrating what can be done with effluent water. The water leaves the plant by one of three channels :—

(i). The River Channel, which has a capacity equal to the maximum flow, (72 m.g.d. or 132 cusecs),

(ii) a main southern channel supplying water to about 1,400 acres of the irrigation area, with a capacity of 15 cusecs, and

(iii) a northern channel with a capacity of 8 cusecs supplying about 400 acres.

The river channel also has irrigation outlets, supplying about 450 acres. The total area now supplied is 2,250 acres. A certain proportion of flow leaves the plant in form of sludge, and there is some loss by evaporation. The available irrigation water is approximately 30 cusecs, and this is divided into amounts of 15 cusecs to the southern area, 7½ to the northern area, and 7½ to the areas supplied from the river channel. One of the principal portions of the latter area is the land lying between the Agra Canal and the River. The dry weather flow is subject to considerable diurnal variation,—the flow from the main pumps varying from about 33 cusecs between the hours 11-0 A.M. and 1 or 2 o'clock at night to about 11 or 12 cusecs for the remainder of the 24 hours. During the time in which the available flow is only 12 cusecs, the northern channel and the river channel receives nothing. The southern channel supplies 8 different sections of land, and each section receives water for 24 hours every fourth day. The sections of land supplied by the northern and river channels receive water for 12 hours every other day. The arrangement is such that each plot of land gets water for about 42 hours per week, and the irrigation duty works out at 97 acres to the cusec. Whether this is over irrigation or under irrigation depends upon the nature of the crop. For crops like wheat so much water is

not required. But for sugarcane or vegetables, this amount of water is not too much, in fact, scarcely enough. In certain areas of the Punjab the evils of over irrigation, of water-logging, and of rise of sub-soil water level are all too evident. With resonable care however, such evils can be avoided in the Okhla-Badarpur irrigation area. The ground is undulating, and there are ample natural water courses which drain the land. The area can be extended to 3,000 acres by pumping, and the duty would then be about 125 acres per cusec.

It will be seen that there is no obligation to put as much as 30 cusecs of water on to the land, or any at all. When the water is not required on the land, it is simply turned down the river channel. It need not even be run to waste into the river, for sluices are provided through which the water can pass into the Agra Canal when that canal is flowing. During rainy spells, when irrigation water is nowhere required, the whole flow of effluent water is discharged into the river.

The effluent water contains a considerable proportion of nitrogen, and therefore acts as a manure as well as watering the crops. About 70 per cent of the nitrogen in the sewage goes in the effluent. The result is that magnificent crops are being obtained, not only is there no failure of crops owing to drought but the quality is excellent, the weight of grain per acre for instance being some 30 per cent above that of a normal irrigated area. Since the land irrigated does not belong to Government, it is the zamindars and cultivators who are reaping the principal benefit. The cultivators of the area are now enjoying a spate of prosperity such as they have never known before. The Joint Water & Sewage Board (which controls the works) does however get a return by making a charge for water supplied. The charges are based on the usual system in the Punjab, a certain amount per acre per crop, and vary with the nature of the crop. The charges are at present double those of the Western Jumna Canal rates for vegetables, sugarcane, etc., and 50 per cent above for grain and fodder crops. The irrigation works have cost Rs. 68,000, and the Board expects to get in the end, some Rs. 20,000 per year as income. The variety of crops grown is considerable. It has however been thought necessary to prohibit the growing of those vegetables which are eaten raw. I may add that the Board has now established a small experimental agricultural farm, 24 acres in extent. The object of this farm is to demonstrate the utility of sewage works effluent as compared with well

water, and particularly to experiment with mixtures of well water and sewage effluent. The layout of the farm, including quarters and a well 45 feet deep equipped with a Persian wheel, has cost Rs. 5,950. It is expected that the working cost will be met by the sale of produce.

II. The second main product is sludge manure. I may remind you that an activated sludge plant, whether on the diffused air or the simplex system, discharges sludge in two distinct forms, crude sludge and activated sludge. Crude sludge comes from the preliminary settling tanks, and contains all manner of substances, ranging from sand to nightsoil. The only satisfactory method of dealing with crude sludge is to put it through a further process known as digestion. In this process the sludge is subjected to complex bacteriological action in which certain constituents of the sludge are liquified, gas is evolved, and the gelatinous matter on which maggots feed is destroyed. Digested sludge is therefore quite free from the danger of fly breeding, in whatever condition it is allowed to lie. In the course of digestion however, a certain proportion of nitrogen is lost, and hence the manurial value of digested sludge is a little less than that of undigested sludge.

The other form of sludge—activated sludge—is of very different character. It may be thought of as more refined, and has the property of settling in about half an hour's time leaving clear water behind. It has a nitrogen content of between 5 and 6 per cent, whereas the nitrogen in crude or digested sludge is between 1 and 1·5 per cent

Large quantities of digested sludge in lump form have been sold from the Delhi Sewage Works. The income during January under this heading was Rs. 700, the price charged being Re. 1 per 100 cu.ft., at the drying beds. Of course the manure costs a great deal more than that by the time it reaches the customer's land, much the greater part of the cost is in the transport. Nevertheless, it is competing successfully with the other forms of manure. An average analysis of dry digested sludge is as follows :—

Nitrogen	...	1 20 %
P_2O_5	...	1·28 %
Sand	...	56·68 %
Moisture	...	3·75 %

the remaining part being classed as organic matter.

Recently however, experiments have been made for producing a better class of manure by a combination of dried digested sludge and dried activated sludge. As is well-known, an absolutely dry and powdered manure is more useful for ordinary purposes. Some small experimental beds have been made in which activated sludge can be dried by a process of decanting the top water and leaving a thin layer of sludge lying on a concrete floor for sun drying. In this way the sludge can be dried in about 3 days, before it has time to putrify, or digest, or breed flies. This is powdered along with digested sludge, and the proportion of the mixture regulates the quality of the final product. It has been proved by experiment that such a mixture cannot breed flies under any circumstances, and a satisfactory manure is produced.

III. The third product is sludge gas. At the Delhi Works we have so far done no more than construct a small gas collecting raft. But it would be possible to collect sludge gas either by the construction of pucca, enclosed digestion tanks, or by the use of reinforced concrete rafts floating on the sewage in the digestion tanks, a plant similar to that in use at the Bhatpara Sewage Works, Bengal. In the latter plant, enough gas is collected to run an 80 H.P. engine for about 16 hours per day. The rafts which are each 20 ft. × 10 ft. cost Rs. 624 each, and there are 27 of them. The calorific value of sludge gas is about 750 B. Th.U. per cubic foot, against about 450 for coal gas. About 40 per cent more power is therefor available from sludge gas. The gas is 70 per cent methane, and burns rather slowly. This means a special adjustment of valves in an engine, and generally involves an unusually high temperature of exhaust. In several sewage works the heat of the exhaust is utilized for heating the sludge in the digestion tanks. In these tanks an optimum temperature of 80° is the most suitable. In this country such heating is not at all necessary during the hot season.

As regards power obtainable, 22 cu.ft. of sludge gas will develop 1 kWh and 200 cu.ft. of raw sludge gas is equivalent to 1 gallon of petrol. A really paying use of sludge gas is as a substitute for petrol. A scheme on these lines will, I believe, be brought into operation in Bombay in due course. The gas will be cleaned, and then compressed to a high pressure and stored in cylinders. Motor buses will be provided with storage cylinders under the chasis, and these will be filled with compressed gas from the main storage at suitable filling points.

The gas is passed out through a reducing valve to the engine, and is quite suitable for use in an ordinary petrol engine. In fact it is better than petrol, as the engine remains cleaner. In case the stock of gas is exhausted, the bus can turn over on to petrol, and get home.

One of my objects in bringing forward this subject is to try to rouse such interest that sufficient users of the products of sewage disposal will be available. For obviously, unless there are sufficient customers for sludge manure, its production and sale cannot be a success. That the land is crying for manure on the one hand, and that excellent nitrogenous value is going to waste on the other, is well known. It is one of the duties of us engineers to prevent waste, and also to assist agriculture as far as possible. The matter does not concern Delhi only, other sewage works are under construction or are being designed, so that the matter is of fairly wide interest.

In conclusion I would again thank you for the honour done me in electing me your Chairman.

MYSORE CENTRE.

Following has been the Programme of Papers and Visits of the Mysore Centre :—

20th April, 1941.	Visit to Hindustan Aircraft Limited, inspection of works, etc. Opening of the Mysore Engineers Association New Building, and reading of the Professional Papers.
21st April, 1941.	Visit to Amco Limited, Government Electric Factory, Elgin Electric Floor Mills. Reading of Professional Papers.
22nd April, 1941.	Visit to Italian Prisoners' camp.
30th May, 1941.	Reading of the paper on Economic Deccan Canals, by Rao Saheb N. S. Joshi.
27th June, 1941.	Reading of the Paper on Underground Supply of Water in the Trap Rock Zone in the Bombay Deccan and other Allied Tracts, by Rao Saheb N. S. Joshi.
25th July, 1941.	Reading of the paper on Approximate method for circulating the deflection of beams, by D. S. Desai.

N.-W. I. CENTRE.

The N.-W.I. Centre held their 14th Annual General Meeting in New Delhi on the 22nd February 1941, with the following programme :—

22nd February, 1941.	Annual General Meeting & Presidential Address. A paper read by Mr. G. M. McKelvie in "Famine Relief & the Engineer."

U. P. CENTRE.

The U.P. Centre held their 20th Annual Meeting in Lucknow in November 1940, with the following programme:—

16th November, 1940.	Annual General Meeting. Discussion of Papers. Dinner.
17th November, 1940.	Visit to All-India Radio Station at Amansi, Sai Bridge & Hume Pipe Factory.
18th November, 1940.	Visit to Loco Workshops & Paper Mills. Inspection of Cement Road Construction.

BENGAL CENTRE.

The Hon. Secretary, Bengal Centre has just recently published a catalogue of the Library of this centre. It is issued free to all members of the Bengal Centre, for others it is priced at Rs. 2. Members of the Bengal Centre who have not received their copies may apply to the Hon. Secretary.

Following books have been added to the Libraries of the Local Centres:—

BOMBAY CENTRE.

BM	12	Specifications for Building Works	W. L. Evershed	1935
BM	13	Modern Ideal Homes for India	R. S. Deshpande	1939
BR	5	Road Bridges in Great Britain	[illegible]	1939
CC	32	Reinforced Concrete Water Towers, Bunkers, Silos & Gantries	W. S. Gray	1933
CC	33	Manufacture of Concrete Roofing Tiles	Baumgarten & Childe	1936
CC	34	Estimating and Cost Keeping for Concrete Structures	A. E. Wynn	1930
CC	35	Design of Domes	J. S. Terrington	
CC	36	Raft Foundations—The Soil-Line Method of Design	A. L. L. Baker	1937
CC	37	How to make good Concrete	H. N. [illegible]h	1939
CC	38	Design and Construction of Air-Raid Shelters	D. H. Lee	1940
CC	39	Design of Arch Roofs	J. S. Terrington	
CC	40	Design of Pyramid Roofs	J. S. Terrington	
CC	41	Concrete Design made Easy	V. A. Dighe	
CC	42	Portland Cement	A. C. Davis	1934
CC	43	Explanatory Handbook on the Code of Practice for Reinforced Concrete	Scott & Glanville	1939

CC 44	Concrete Surface Finishes, Renderings and Terrazzo		1935
DR 9	Sewage Disposal	N. V. Modak	1940
EE 124	Electrical Technology	H. Cotton	1939
EE 125	The Performance and Design of Direct Current Machines	A. E. Clayton	
H 52	Irrigation in India—Review for 1937-38	Govt. of India	1940
H 53	Hydraulics and Machines of Fluids	E. H Lewitt	1939
F 7	Kanara Forests	T. K. Mirchandani	1941
ME 21	Theory of Machines	Toft & Kersey	1939
ME 22	Applied Thermodynamics	W. Robinson	1937
MS,G42	Broadcasting in India	Govt. of India	1940
ST 25	Theory of Structures	H W. Coultas	1938
II-IRC, P 6	Proceedings of the Sixth meeting	Vol. VI	1939
BI-RE,J 11	Journal	Vol. LIV	1940

U. P. CENTRE.

1. Properties & Strength of Materials. J.A. Cormack & E.R. Andrew.
2. Comparison of Regulations in force in various Countries for the Erection of Overhead Lines. Pub. by Intl. Elec.—Tech Commission.
3. Hydro-Electric Survey of India, Vol. II F.E Bull & J.W. Meares.
4. Mussoorie Hydro-Electric Scheme Vol II, Plates (Completion Report) Govt. U P. Pub.
5. Electrical Technology. H. Cotton.
6. Physics (A text book of Magnetism & Electricity) J Duncan & S C. Starling.
7. Accumulator Charging. W S. Ibbetson.
8. Bijli Darpan, (Hindi) S.P. Dutt.
9. Mechanical Engineers' Pocket Book. B B. Low.
10. Elementary Applied Mechanics. A. Morley & W. Inchley.
11. Ripper's Heat Engine. Revd. by A T J. Kersey.
12. Steam & Other Engines. J. Duncan.
13. Explanatory Handbook on the code of Practice for Reinforced Concrete. W.L. Scott & W.H. Glanville.
14. Making Pre-cast Concrete for Profit. A E. Wynn.
15. Reinforced Concrete, Theory & Practice (The Students' Text book of—). R.P. Mears.
16. Reinforced Concrete Design (Practical Examples of—). C.E. Reynolds.

17. Manufacture of Concrete Roofing Tiles. R.H. Baumgarten & L.H. Childe.
18. First Aid for the Ailing House. Whiteman.
19. The Book of the Modern House. P Abercrombie.
20. Interior Decoration To-day. H.G. Hayes Marshall.
21. Colour in Interior Decoration. J.M. Holmes.
22. Design, Cost, Construction and Relative Safety of Trench, Surface, Bomb-Proof, and other Air-Raid Shelters. Ove N. Arup. Charles Eley.
23. 20th Century Gardening.

    Modern Theatres and Cinemas. P. Morton Shand.
24. Design of Arch Roofs. J.S. Terrington.
25. Highway Design & Construction. A.G. Bruce.
26. Tar Roads. A.C. Hughes, W.G. Adam & F. J. E. China.
27. River Engineering. F.J. Taylor.
28. Report on the Ganges Canal Vol. I & Vol. II, Estimates Vol. III Plans Capt. J. Crofton.
29. Irrigation in Southern Europe. C.C. Scott Moncrieff.
30. Irrigation Works (Thomason College Mannual) Ed. J. G. Medley.
31. Italian Irrigation Vol. I & Vol. II. P. B. Smith.
32. Fluid Mechanics for Hydraulic Engineers. H. Rouse.
33. Ground Water. C. F. Talman.
34. Indian Railways, Schedule of Dimensions. Govt. of India Pub.
35. The Indian Railways Act 1890, Govt. of India Pub.
36. Cole's Permanent Way, Gordon Hearn.
37. Locomotive Engineers' Pocket Book.
38. Drainage & Flood Control Engineering. G.W. Pickels.
39. Wells & Bore-Holes for Water Supply. J.E. Dumbleton.
40. Specification 1939. Ed. F. R. S. Yorke.
41. B.S.S. for Portland Cement.
42. Water Hyacinth in U.P. Govt. U.P. Pub.
43. Cement Chemistry in Theory & Practice. Hans Kuhl.
44. Indian Water Power Plants. Dr. Prof. Shiva Narain.
45. Great Engineers. C. Matschors.
46. Regional & Town Planning. W.H. McClean.
47. Financial Handbook Vol. III T.A. Rules, U.P. Govt. Pub.
48. General Provident Fund Rules. U.P. Govt. Pub.
49. The City of Taj. R.C. Arora.

B. S. CHETTI, Esq., M.A., B.Sc. (Edin.), M. Inst. C.E., M.I.E.
Chairman, South India Centre.

NOTE—The Presidential address read at the Annual Meeting of the South India Centre on 25th November 1940 was published in the April issue of the Journal

SPECIALISED SECTIONS.

The amended Resolution No. 15 as passed at the Annual General Meeting of 1940 is as follows:—

"This Institution should start specialised sections in different branches of Engineering and invite collaboration from other professional bodies like the Indian Roads Congress, the Central Board of Irrigation and the Punjab Engineering Congress in the best interests of the Engineering profession." Copies of this Resolution were circulated to all local centres with a request to give effect to it. At Council Meeting, 259 following further Resolution was passed "Resolved that at the next Annual General Meeting of the Institution the following 2 separate sections be opened:—

1. House and Town Planning (Mr. B. R. Kagal be requested to arrange for the same) Mr. Kagal agreed to do so.

2. Hydro-electricity (Mr Dildar Hossain be requested to arrange for the same) Mr. Dildar Hossain agreed to do so."

Mr. B. R. Kagal has issued the following questionnaire in this connection and members are requested to send their views to him at the following address:—

Land and Development Officer, New Delhi.

Questionnaire

1. Are you connected with a town planning, a town improvement or a slum clearance scheme; or with any Improvement Trust?

2. If so, in what capacity?

3. What were the methods employed to determine the extent of over-crowding or slum conditions of the area under improvement?

4. Who took the initiative that led to the preparation and execution of the scheme?

5. What are the minimum standards to which the improved conditions are designed to comply as regards:

(a) floor area per person,

(b) segregation of the sexes,

(c) number of houses per acre,

and (d) number of persons per acre.

6. How do these minimum standards compare with the standards which you consider suitable for general Indian conditions?

7. What is the agency employed for executing the scheme?

8. What is the reaction of the public to:

(a) the principles of the scheme, and

(b) the details of the execution of the scheme.

9. If the public reaction is not favourable, to what extent is, in your opinion, the hostile attitude justified?

10. Are vested interests represented in the local bodies; if so, to what extent? Describe them.

11. What action are the authorities taking:

(a) for giving publicity to the scheme,

(b) to educate public opinion against slum conditions both for health and sociological reasons.

12. Have the engineers in charge of the slum clearance scheme previous training or experience of this kind of work; if so, please give a brief account of the same.

13. How is the scheme financed?

14. Is the scheme a part of a Master plan; if so, what is the scope of the latter?

15. Is the scheme distributed over a number of years; if so, give a brief outline of the distribution and the reasons thereof.

16. What are the principles underlying the scheme, for rehousing the dishoused population from the cleared area?

17. Has full provision been made for the dishoused population, if not, what portion of that population is provided for in the rehousing schemes?

18. What are the means adopted to encourage or finance the public to build their own buildings in the developed or rehousing areas?

19. Are the existing transport facilities adequate to cope with the requirements of the dispersed population cheaply and efficiently?

20. If not, have additional facilities been provided to meet the needs of the redistributed population? Describe them briefly.

21. How would, in your opinion, the proposed redistribution of the slum population:

(a) affect the basic Industries that maintain the population, and

(b) affect the social balance, as for instance concentration of population of the same status in a place instead of mixing different classes by judicious planning of "Zones".

22. Would you be in a position:

(a) to attend the meeting of the Housing and Town Planning Section of the Institution of Engineers in Bangalore next January,

(b) to read a paper there at,

(c) to participate in the general discussion, and

(d) to exhibit plans of the work under you.

23. In case you are unable to attend, would you be able to send details and plans of the schemes under you, for the benefit of the Town Planning Section?

24. Please offer any other remarks you may wish in regard to the scheme.

25. Have you any suggestion to offer for the working of the Housing and Town Planning Section of the Institution of Engineers?

Note.—The questionnaire issued by the Housing and Town Planning Section of the Institution of Engineers is intended to elicit information on the subject with a view to—

(a) ascertain the progress the country is making in this direction,

(b) to gauge the forces the workers have to contend with, and

(c) to bring together the workers as far as and as soon as possible on a common platform for the furtherance of the cause.

The nature of the questions would indicate that they are intended both for the Engineers and or the administrative officers. The co-operation of all persons, engineers and laymen, councillors and social workers, is solicited. In replying to the questions suitable ones may be selected for a answers and the others left out, if so desired. Co-operation in any manner or form would be most welcome.

BOOKS RECEIVED

Following books have been received at the Headquarters for which the Council desire to make an acknowledgment and express their appreciations to the donors.

Current Hydraulic Laboratory Research in U. S. A., U. S. Dept. of Commerce, National Bureau of Standards, Bulletin IX—January 1941.

Bulletins—International General Electric Co. of America.

Glossary of Technical and Vernacular terms in connection with irrigation in India, Central Board of Irrigation.

Year Book 1941—American Institute of Electrical Engineers.

Annual Report (Technical) for 1939-40 of the Central Board of Irrigation, India.

EXCHANGE MEMBERSHIP PRIVILEGES.

Reciprocal arrangements have been completed with the American Society of Civil Engineers. This will entitle members of this Institution when on a visit to the United States of America to membership privileges of that Society for a period of 3 months. Members visiting U. S. A., and desirous of availing themselves of these privileges are requested to obtain a letter of introduction from this office. Following letter has been received from the Secretary, American Society of Civil Engineers of New York. This has been approved by the Council, and is re-produced below for the information of our members.

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

THIRTY-THREE WEST THIRTY-NINTH STREET, NEW YORK

March 31, 1941.

Mr. A. R. NISSER
Technical Secretary,
The Institution of Engineers (India),
8, Gokhale Road,
Calcutta, India.

Dear Mr. Nisser

This will acknowledge with thanks your letter of February 11, 1941, advising that the Council of your Institution had passed a resolution for exchange membership privileges with our Society, available for three months, toward the mutual interests of members of the two organizations.

I take it from the information in your letter that this membership proposal is to furnish your members with proper credentials upon any visit to this country, so that we may feel free in extending to them the privileges of the headquarters of this Society and to assist them in their visit.

If this is the intent of the resolution of your Council, I can assure you that we will be delighted to welcome any of your members upon their visit to this country and to extend such courtesies as are within our power to them. I can assure you also that any of our members who likewise may visit your country will be given, if they so request, the necessary credentials from this Society to you.

Sincerely yours,

Sd. George T. Seabury,

Secretary.

PERSONAL.*

We offer our felicitations to the following members of the Institution for inclusion in the last Birthday Honours' list.

MR. J. J. GHANDY, C.I.E., M.I.E.
HON. LT. T. R. S. KYNNERSLEY, O.B.E., M.C., M.I.E.
MR. F. SIMS, M.B.E., M.I.E.
SIR LEONARD WILSON, Kt., M.I.E.
RAI BAHADUR T. N. KUNZRU, M.I.E.
RAO BAHADUR N. S. JOSHI, M.I.E.

Following members of the Institution are on active war services.

LT.-COL. F. C. TEMPLE, M.I.E.
CAPT. N. B. GADRE, M.I.E.
HON. LT. T. R. S. KYNNERSLEY, O.B.E., M.C., M.I.E., R.I.N.V.R.
LT. D. P. R. CASSAD, A.M.I.E.
LT. G. C. GAUTAM, Stud.I.E.

Following members are actively associated in war work.

SIR GUTHRIE RUSSELL, K.C.I.E., M.I.E.
MR. G. E. BENNETT, M.I.E.
DR. G. W. BURLEY, M.I.E.
DR. A. H. PANDYA, A.M.I.E.
MR. T. K. MIRCHANDANI, M.B.E., A.M.I.E.
PROF. A. VISWANATH, M.I.E.

The services of MR. JOHN CHAMBERS, O.B.E., M.I.E., have been placed at the disposal of the Government of India.

MR. BIREN MOOKERJEE, M.I.E., is the SHERIFF of CALCUTTA for the current year. He has recently been appointed a member of the National Defence Council.

* Members are requested to send news of personal activities to the Technical Secretary for inclusion under this column.

DR. A. H. PANDYA, D.Sc., A.M.I.E., Principal, Bengal Engineering College, has been appointed as a Regional Inspector of Technical Training for the Eastern Scheme by the Government of India. The Technical training scheme has as its main object the training of suitable young men in different trades by the utilization of all existing technical institutions, factories and workshops for this purpose.

There are two schemes of technical training now in operation at the Bengal Engineering College, Sibpore. The first of these schemes is sponsored by the Civil Aviation Directorate of the Government of India with the specific object of providing the Indian Air Force with personnel thoroughly trained in work associated with the maintenance of Aircraft. The other scheme is controlled by the Labour Department of the Government of India, with the object of training skilled mechanics in various trades for employment in the Indian Army Ordnance Corps or other technical branches of the Indian Army, in Ordnance Factories and on war production work in civil industry. The total number of technicians under training at present is approximately 500.

In honour of his recent election as an Honorary Member of the Institution of Engineers (India), the Hyderabad Centre were "At Home" to HIS EXCELLENCY SIR AKBAR HYDARI, at the Exhibition Hall, on Wednesday the 18th June, 1941, when a large gathering of distinguished officials and others graced the occasion. MR. SYED ALI RAZA M.I.E. Chairman and MR. DILDAR HUSAIN, M.I.E., the Hon. Secy. of the Hyderabad Centre, were principally responsible for this pleasingly successful function.

(Contd . from p. 517)

Resolved that this meeting places on record, its deep sense of sorrow at the sad demise of M. L. Misra, late lecturer, Thomason College, Roorkee. The Committee deplores the loss which our Institution has sustained in his death, and sympathises with the family of the deceased and authorises the Honorary Secretary to convey to them its sincere condolence in their sad bereavement."

NEW MEMBERS

Since last publication following names have been added to the membership Roll (corrected up to 3rd July 1941):—

HONORARY MEMBERS.

His Excellency Sir William Hawthorn Lewis, K.C.S.I., K.C.I.E.
His Excellency Sir Hugh Dow, K.C.S.I., C.I.E.

MEMBERS.

No.	Name.		Address.
918.	Mascarenhas, W. X., B.E. (Civil)	...	Principal, College of Engineering, Poona.
919.	Ellis, L. G.	...	Manager, Messrs. F. & C. Osler Ltd., Scindia House, Queensway, New Delhi.
*920.	Mehandru, T. R.	...	Engineer & Architect, 6, The Mall, Lahore.

ASSOCIATE MEMBERS.

No.	Name.		Address.
1477.	Agarwal, S. R., B.Sc., C.E.	...	Canals, Bulandshahr.
1478.	Chatterjee, S. P., B.Sc., B.E.	...	P.59, New Shambazar Street, Calcutta.
1479.	Shah, C. H., B.E. (Civil)	...	Structural Engineer, Plot No. 321E, Jariwala Mansion, Vincent Road, Matunga, G.I.P., Bombay.
1480.	Sirajuddin Gasudraz, S., B.E.		Asst. Engineer, S.I.Rly., Tinnevelly Junction, S.I.
1481.	Pal, B. C., B.Sc. (Eng.)	...	T.G. New Civil Lines, Lucknow, U.P.
1482.	Varma, R. K., C.E.	...	Chief Consulting Engineer & Architect, Messrs. Varma Bros., Connaught Circus (Opp. Fire Brigade), New Delhi.
1483.	Shahane, N .G., B.E. (Civil)	...	"Luxmi Prasad," Block G. Gokhale Road (North), In Ranade Road Extension, Dadar, Bombay.
1484.	Chowdhury, Kamaladas	...	S.D.O., Cantonment Board, Agra.

*Transferred from Associate Membership.

ASSOCIATE MEMBERS (*Contd.*)

No.	Name.		Address.
1485.	Ramamurthy, K. S., B.E. (Mech.)	...	Manager, The Mysore Lamp Works Ltd., Malleswaram, Bangalore.
1486.	Ghosh, Susil Kumar, B.E.	...	66, Chenab Road, Jamshedpur, B.N.Rly.
1487.	Singh, Iqbal	...	Asst. Executive Engineer, N.W.Rly., Bahawalnagar.
1488.	Gupta, Birendra.	...	Executive, Engineer, Benares Hindu University, Amethi House, Lanka, Benares.
1489.	Salukhe, V. B., B.E. (Civil)	...	District Engineer, District Local Board, Sholapur.
1490.	Azeez, A., B.E.	...	Asst. Engineer, S.I. Railway, Golden Rock, Trichinopoly.
1491.	Pansare, R. G., B.Sc. (Eng.)	...	Ganesh Sadan, 4, Jawaharkunj, Ellis Bridge, Ahmedabad 6.
1492.	Vernekar, V. S., B.E. (Civil)	...	Civil Engineer, Messrs. Pallonji Edulji & Son., Cadel Road, 21, Bhagirathi Sadan, Mahim, Bombay.
1493.	Patel, N .K., B.E. (Civil)	...	Tapti Bridge Engineer, Tapti Bridge Work, Kathor, via. Sayan B.B.& C.I. Rly.
1494.	Baleshwar Nath, B.Sc.	...	Asst. Engineer, Hardoi Divn., Sarda Canal, Hardoi, U.P.
1495.	Philip, M., B.A., Grad.Inst. E.E.	...	Asst. Engineer, Messrs. Harrisons & Crosfield Ltd., Engineering Department, Quilon, Travancore State.
**1496.	Bilimoria, R. K., B.E. (Civil)	...	City Engineer's Dèpartment, Bombay Municipality, Bombay 1.

STUDENTS.

No.	Name.		Address.
920.	Vesuna, K. R., L.M.E.	...	17A, Rustom Baug, Bombay, 27.
921.	Gupta, B. M. L.	...	C/o S.D.O, Air Force Sub-Division, Dak Bungalow, Tinsukia (Assam).
922.	Sankarasubban, P. R.	...	C/o V. Rama Iyer Esq., Anman Sannadhi Street, Shencottah, Travancore State.

**Life Associate Member.

STUDENTS (*Contd.*)

No.	Name.		Address.
923.	Sharma, S. B.	...	A. P. W. Inspector Rajaka Shahaspur, Dist. Moradabad.
924.	Joshi, D. R.	...	623/22, Sadashiv Peth, Poona 2.
925.	Basu, Nirad Baran	...	Apprentice, Rifle Factory, Ishapore, 24 Parganas.
926.	Varma, Mulraj	...	Superintendent, E/M, M.E.S., Saugar.
927.	Lakshmana Swamy, A.		C/o L. N. Narasimharao Esq., Modibada, Cantonment, Jubbulpore, C.P.
928.	Kajale, G. S.	...	84, Hindu Colony, Dadar, Bombay.
929.	Khajotia, P. P.	...	Readymoney Colony, Tata Building No. 4, Tardeo, Bombay.
930.	Naidu, V. Narayan Swamy	...	C/o Dr. V. T. Naidu, D.M.O., S. I. Rly., Golden Rock, Trichinopoly.
931.	Bhargava, T. N.	...	'Amar Niwas', Nana Bhai Road, Desai Pole, Surat.
932.	Gupta, Hari Krishna	...	Overseer, Central P.W.D., Ajmer.
933.	Ghose, Nirode Kumar	...	110, Ashutosh Mukherjee Road, Calcutta.
934.	Deshukh, D. L.	...	Work Charged Overseer, P.W.D., Road Sub-Division, Mandla, C.P.
935.	Solomon, R.	...	"Ivorine", 132, Churchgate Reclamation, Fort, Bombay.
936.	Makdumi, S. A.	...	App. P.W.I. (E.I.R.), Block No. 12, Room No. 8, Railway School of Transportation, Chandausi, U.P.
937.	Sharma, M. B., D.M.E.	...	Engineer-in-charge, Messrs. Ratodero Electric Supply Co., Ltd., Ratodero (Sind).
938.	Bhadsavle, T. D.	...	10B, Vasanji Park, Nayagaon Cross Road, Dadar (G.I.P.), Bombay No. 14.
939.	Karunakara Rao, J. V., B.E.	...	"Anandabhavanam", No. 8, Ritherdon Road, Vepery, Madras.
940.	Srinivasan, V.	...	Upper Subordinate Engineer, Messrs. Gannon, Dunkerley & Co., Ltd., Salem Gravitation Main Works, Suramangalam, Salem Junc., S.I.R.

STUDENTS (Contd.)

No.	Name.	Address.
941.	Vaikunta Rao, K. ...	C/o Dr. K. N. Murty, Maharani Hospital, Jagdalpur, Bastar State, via Raipur.
942.	Gupta, Bhagwan Das ...	Overseer, Duni Barrage, P.O. Amaria, Dist. Pilibhit, U.P.
943.	Raju, P. V. ...	C/o P. Peddi Raj Esq., Advocate, Ellore, M.S.M.Rly.
944.	Basu, Asim Kumar ...	P.10, Diamond Harbour Road, Alipore P.O Calcutta.
945.	De, Krishna Chandra, D.C E.	Head Draftsman, Improvement Trust, Nagpur.

The following candidates have not yet confirmed their election (corrected up to 3rd July 1941):—

MEMBERS.

E. A. Moore	26-4-40.	O. C. Rickett	17-6-41.
Probhat Chandra Neogi Meherali Fazil	30-5-41.		

ASSOCIATE MEMBERS.

W. E. J. Beeching	29-3-40.	Babu Ram Sharma G. K. Chandiramani M. K. Joshi C. C. Patel M. K. Batlivala D. R. Bhalerao	30-5-41.
W. A. R. Baker	28-7-40.		
M. S. Sitaram Rao J. S. Gupta	29-8-40.		
B. P. Sangal	26-9-40.	P. Venkata Rao D. R. Vaidya S. R. Chaudhuri P. F. Lakhani Lieut. M. G. Raju	17-6-41.
K. M. Kantawala M. N. Subandh	10-3-41.		
R. M. Hemnani	25-4-41.		

STUDENTS.

D. T. Vaidya; M. S. Viswanathan	26-9-40.
Md. Siddick H. Ayub Menon; S. R. Sen Gupta	28-11-40.
Raj Kumar; P. V. Govinda Rajan	31-1-41.
K. P. Chattopadhyay; Keshab Dev Malhotra; Jugal Kishore Agarwala; B. J Mainkar	10-3-41.
A. Venkateswarlu; Phiroze D. Bharucha	25-4-41.
Vishwambhar Prasad; A. Sunder Raj; Amiya Kumar Cuha; Sunil Kumar Sen; Ranendra Nath Chakrabarty; M. K. Das Gupta; B. R. Rajagopalan; K. Rajanraju; Mohd. Aslam Sheikh; K. A. Kelkar; Rajnarayan Mitra; P. Mahadevan; P. Aboo Backer	30-5-41.
S. D. Bharucha; V. S. Mankikar; Prithvi Raj Puri; Lakhmi Chand; Ajoy Kumar Sircor; Dhirendra Nath Goswami; Sudhiranjan Banerjee; Parimal Kumar Roy; Sitansu Kumar Roy; Nirmal Kumar Nandi; Sunil Kumar Ghose; Kanu Priya Chowdhury; Maheswar Prosad Barman; Bijon Kumar Mitra; Pranab Kumar Das; Kanak Kumar Paul; Sudhamoy Dutta	17-6-41.

List of applications under consideration as on 3rd July 1941 :—

(a) UNDER CONSIDERATION OF LOCAL CENTRES :—

BENGAL.

Anindya Nath Chatterjee
Md. Abdul Latif
Santosh Kumar Paul
Parimal Kumar Mukherjee
Rajendra Singh
Rabindra Nath Das Gupta
Susil Kumar Das Gupta
Joy Deb Gupta
M. A. Rashid
Jagat Narain Malik
R. P. Varma
A. A. M. Obaidul Haque
M. Ashraf Ali Khan
Arun Kumar Das Gupta
Nikhil Nath Chatterjee
A. Viswanadham
D. B. Nagarker

N.B. The date against a name indicates date of election.

BOMBAY.

A. S. Somappa Sastry
M. N. Chinoy
C. D. Shukla
G. K. Ahuja
K. C. Desai
P. J. Bhavanani
J. K Mehta
N. J. Balani
R. B. Chitnis
H. Narayana Rao
A H Nanavaty
H. V. Gopal Rao.

HYDERABAD.

Mir Iqbal Ali Khan
Md. Muzaffaruddin Ansari
N. N. Reddy
L. Gangadar
S K. Subba Rao
B. V. Deshmukh.

NORTH-WEST INDIA.

Chetan Das
Lekha Raj Grover
Manohar Singh
Om Prakash Sharma
J. W. Keswani
Sheikh Abdul Shakoor
Anwar-ul-Haq Qureshi
Balmukand Arora
Jagir Singh
P. K. Sen
Abdul Latif Olakh
Kailash Ch. Jain
Muzaffar Din Ahmad
Bhupendranath
B. B L. Kichlu
K. L. Sahni
Jogindar Pal Bajaj
L. N. Varma
Meraj-ud-Din
S. B. Bhatnagar
S. N. Handa
G. Das Suri
Gur Charn Singh
L. Ishar Das
Prem Narain Sud.

SOUTH INDIA.

S. Varadaraja Sarma
P. Venkataramana Raju
V. B. Chiniwalla
T. V. Sankarankutty Warier

UNITED PROVINCES.

S. P. Sahni
Satinder Nath Gupta
S. L. Gupta
Deep Chand Gupta
G. N. Dikshit
S. B. Mathur
Syed Zahurul Hasan
R. J. Dhumal
C. C. Chakravarti
Beni Madhav Singh
Paresh Ch. Dutt
Mohan Ch. Pande
V. M. Rane
Om Prakash Sharma (1)
Aniruddha Mishra
S. M. Irfanallah
Mata Prasad Misra
Om Prakash Sharma (2)

(d) INCLUDED IN BALLOT LIST NO. 273.

Dr. Nand Singh
Indu Bhusan Majumdar
Sailendra Kumar Roy
T. B. Domingo
U. P. Mullick
M. Najabat Ali
K. C. Sood
N. R. Magal
B. N. Chopra
B. C. Ganguli
Manojkumar Majumdar
Salil Kumar Roy
Azim Uddin Ahmed
Ajit Kumar Roy
Md. Mosharraf Ali
Mainul Islam
N. P. Neemuchwala.

(c) INCLUDED IN BALLOT LIST NO. 274.

John Sword
B. S. Raju Iyer
S. P. Hajeley
Yadava Mohan
Moti Ram
Akhil Chandra Mitra
M. S. Nerurkar
D. Krishnamurty
V. G. Apte
L. G. Dhayagude
Krishna Kumar
M. N. Tapaswi
Amaresh Chandra Roy
Shyam Sunder Gupta
Sayta Vrata Agarwala
Bhola Nath Vaish
Pratap Singh Perti
Lakhmi Chand
Ramendra Nath Mitra
Hanuman Prasad
Manohar Narayan Ranade
A. J. D'Costa
S. Sivaraja Pillai
T. V. Venkataramani
Ranjit Kumar Sikdar
A. Rajaratnam
Insha Allah Khan
P. V. Srinivasa Iyengar.

(d) TO BE INCLUDED IN BALLOT LIST NO. 275.

Charat Ram
Kamal Prasanna Roy
Bidhu Bhusan Ghosh
Kalidas Bhattacharjee
Sarat Chandra Dam
Shivaram Bhatta
Abdur Razzaq Awan
Surat Singh
Asim Kumar Sarkar
Balen Kumar Bose
Raghunath Sharan
Syed Ali Reza
E. R. Shroff
R. S. Mehta
Hormasji P. Bharucha
V. S. Ratnam
A. B. Paramanand
Lalit Mohan De
Naresh Ch. Das Gupta
K. Venkoba Rao
V. Krishnamurthi
S. Kumaraswamy
Ziauddin Ansari
M. P. Raghavendra Rao
S. M. Younus
Sadiq Ali Khan
Bala Pershad
Syed Sarwar Hassan
S. R. V. Iyer
M. L. Narasimiengar
P. Shunmugam
B. D. Khadepaw
J. P. Naegamvala

(e) BEING DEALT WITH AT THE HEAD OFFICE:—

H. B. Neale
P. N. Venkata Rao
D. R. Sesai
G. D. Parekh
S. Somaiah
S. S. Gairola.

ADDRESSES WANTED

A list of members whose mail has been returned by the Dead Letter Office is given below together with the addresses as filed in the Institution records. Any member knowing the present address of any of these members is requested to communicate with the Headquarters.

MEMBERS.

Name.	Address.
T. S. Dawson	... 19, Cranbury Avenue, Southampton, England.
C. J. H. Bolton	... Crathorne, Godolphin Road, Weybridge, England.
A. W. H. Matthews (*Major*)	... C/o Lloyds Bank Ltd., G2 Branch, 6, Pall Mall, London.

ASSOCIATE MEMBERS.

U. Roy	... P.195, Raja Basanta Rai Road, P.O. Kalighat, Calcutta.

STUDENTS.

O. G. C. Mears	... 28, Central Avenue, Suite No. 11, Calcutta.
Hari Sadhon De	... C/o S.D O., No. II Sub-Division, Damodar Canal Division, P.O. Rondia, Burdwan.
M .E. Hussain	... Surveyor's Assistant, M.E.S., Reconstruction, Quetta.
Ajit Kumar Sinha	... Civil Engineer, 1/1/1-c, College Square, Calcutta.
Sudhansu Kumar Banerjee	... 8/1A, Bipin Mitra Lane, Shambazar, Calcutta.
Rabindra Nath Banerjee	... 6A, Duff Lane, P.O. Beadon Street, Calcutta.
Sukhbir Prasad	... Overseer, P.W.D., Jhansi.

OBITUARY.

The Council record with deep regret the death of the following members of the Institution:—

Abdul Wahid	C. Hanumanta Rao
G. D. Agarwal	P. B. Behramji, M.I.E.
[1] S. N. Bhaduri (*Rai Bahadur*)	[2] M. L. Misra

[1]Following resolution was passed by the Committee of the U. P. Centre of the Institution of Engineers (India), at its meeting held on January 15, 1941, at Kaisarbagh, Lucknow.

"***Resolved*** that this meeting places on record its deep sense of sorrow at the sad demise of Rai Bahadur S. N. Bhaduri, M.I.E., Chief Engineer of Gwalior State. The Committee deplores the loss which our Institution has sustained in his death and sympathises with the family of the deceased and authorises the Chairman to convey to them its sincere condolence in their sad bereavement.

"***Resolved*** further that this meeting be adjourned for 10 minutes as a mark of respect to the memory of the deceased."

[2] See page 509

BRITISH STANDARD SPECIFICATIONS

The following notes on the outstanding points in connection with the British Standard Specifications recently issued are published for information of the members:—

B.S. 925 and 926. WAR EMERGENCY SPECIFICATIONS FOR OILS, THINNERS, DRIERS AND EXTENDERS.

B.S. 927 and 928. WAR EMERGENCY SPECIFICATIONS FOR PIGMENTS, WHITE, BLACK AND COLOURED.

B.S. 929. WAR EMERGENCY SPECIFICATION FOR READY MIXED PAINTS.

Many materials normally used in the paint industry have to be imported and the Government has found it necessary to prohibit or restrict their use in order to relieve demands on shipping and to conserve currency. This has necessitated a complete review of the series of British Standards for paint materials.

Where necessary the existing requirements of these Specifications have been relaxed so as to allow the use of material of lower standard quality, and in addition, the use of alternative materials has been provided for.

The use of alternative materials provides in some measure a means of overcoming the present and anticipated difficulties, and the specifications now include certain materials not hitherto covered by specifications, particularly for materials for use as extenders. The alternative materials are for the most part home products. In cases where materials are no longer available, substitute materials are suggested.

The modifications and additional specifications are to be regarded as separate war-time specifications, and in no way affect the existing specifications which are retained to provide a standard for materials for export. In this field the level of quality demanded by the existing British Standard now recognised throughout the world must be maintained in order to uphold the prestige of British exports.

The War Emergency Specifications should always be used for materials for home consumption, and it is hoped that having regard to the circumstances that have necessitated their preparation any inconvenience occasioned by the change should be readily accepted as a necessary national duty, since any inconveniences that may occur can be in no way serious.

The three separate documents have been issued bearing the reference numbers given above.

OIL FOR PAINTS.

The new specification for oil for paints is interesting from two outstanding aspects. One is that it allows a 25 per cent of other drying oils to be admixed with the linseed oil, and thus increases the quantity of oil available for use in paints. The other is that it is a "heat-treated" product and as such is much

more viscous than raw or refined oils. The increased viscosity results in an appreciable reduction in the quantity of oil required for a paint being effected. This represents an important economy in the use of material.

It is stipulated that the additional drying oils must have an iodine value more than 120. A wide range of oils is available for use and it will therefore be incumbent on manufacturers to keep a close watch on the quality and characteristics of any oils they employ.

ADDITIONAL EXTENDERS.

There are a number of materials available in this country which are suitable for use as paint extenders. Complete specifications have been included for barytes (Type B), precipitated barium carbonate, china clay, kieselguhr, strontium sulphate, whiting, (Paris white) and witherite.

In addition to these there are a number of others which might be used, such as talc, french chalk, mica, slate powder, coloured earths, sands and other silicious materials generally, and these are covered by a single specification entitled "Miscellaneous Extenders." An introductory note to this Specification emphasises that when use is made of any of these materials it is essential that care should be taken to ensure that they are satisfactory for use in paint and that they will not result in incompatibility, *e.g.*, fading.

ALTERNATIVES FOR CHROMES.

There are several materials which can be used as alternatives to chromes, for example the yellow chromes may be replaced by yellow oxides of iron, red and organic oxides of lead produced from yellow basic dyestuff, sulphides and selenides of cadmium. Whilst the green chrome pigments may not only be replaced by green organic pigments but by mixtures of any of the foregoing yellow pigments with blue pigments.

Separate specifications are given for the alternatives for yellow chromes and for green chromes. Details of the properties of the alternatives as compared with the chrome pigments themselves is also given and this should prove a very valuable guide.

Ready Mixed Paints. The new specifications for paints have some interesting features. Provision has been made for a standard priming paint (white lead base) and for two undercoating paints (white lead base and lithopone base) in six standard colours.

There is a wide range of finishing coat paints (white lead zinc oxide or lithopone base) and the finish is oil gloss.

LIGHT OUTPUT TEST OF CINEMATOGRAPH PROJECTORS (B.S. 930-1940.)

This Specification gives a simple method of assessing the light output of sub-standard cinematograph projectors. It is primarily intended for the assistance of those buying such projectors and will enable them to compare the

light output of different types and also keep a check on any reduction in output after a period of use. The apparatus requisite is readily available in any physics laboratory.

AUTOMOBILE LAMPS. (B.S. 941.)

The British Standards Institution will issue shortly at the request of the Ministry of Aircraft Production a Specification for Electric Lamp Bulbs for Automobiles, B. S. 941.

The Specification covers 6 and 12 volt bulbs for head, side and rear lamps of motor cars and the motor car glass of goods vehicles. It is not intended to cover lamps for public service vehicles or for heavy commercial goods vehicles.

The Specification has been drafted with war-time requirements and conditions in mind; it will be revised in due course as regards some of the technical details with a view to meeting peace-time requirements.

METAL ARC WELDING AS APPLIED TO TUBULAR STEEL STRUCTURAL MEMBERS (B.S. No. 938.)

In the revision of B.S.538, Metal Arc Welding in Mild Steel as applied to General Building Construction, which was issued in April 1940, a note was included in the Foreword pointing out that the requirements of that Standard are not applicable to the welding of tubular steel sections. It was considered that the factors affecting the welding of tubes, namely the quality of steel of which the tubes are made and the forms of welded joint which are appropriate—were sufficiently diverse from those for the welding of the normal mild steel section as to justify the preparation and, issue of a separate publication.

The above British Standard (B.S. 938 Metal Arc Welding) as applied to Tubular Steel Structural Members has therefore been prepared to provide for the welding of tubes in steel construction. The economy in weight that can be obtained by using this method of construction in roof trusses, is mentioned in Bulletin No. 8 of the Department of Scientific and Industrial Research.

NEW BRITISH STANDARD FOR DOMESTIC ELECTRICAL REFRIGERATORS (B.S. 922.)

The British Standards Institution has added to its list of Standards for domestic electrical apparatus by the publication recently of B.S. 922, Domestic Electrical Refrigerators. The Standard is based largely on the Household Electric Refrigerator Standards prepared by the American National Electrical Manufacturers' Association, the National Test Code for Domestic Refrigerators issued by the Standards Association of Australia, and the provisions of the Canadian Electrical Code issued by the Canadian Engineering Standards Association. It comprises methods of computation of cabinet volume and food-storage surface area, certain constructional details, clauses covering the rating of the motor, requirements for the electric circuits and a section on testing.

RUBBER MATS FOR ELECTRICAL PURPOSES (B.S. No 921.)

The British Standard Specification for Rubber Mats for Electrical Purposes, B.S. 921 has just been issued by the British Standards Institution in order to meet the demand for a standard specification for these mats, but it is not intended to imply that rubber mats should afford the sole means of protection when working on electrical circuits.

Wherever possible further precautions should be taken against the risk of shock and short-circuit. In this connection attention has been drawn to the fact that, in places in which the Home Office Electricity Regulations apply, it may be illegal in certain cases for work to be done on live conductors or apparatus at pressures in excess of medium pressure, *i.e.*, 650 volts; as for instance in Home Office Electricity Regulation 18 (d), which implies that work may be carried out only on sections which have been made dead and suitably screened from adjacent live conductors.

The specification covers the scope, construction, thickness and weight and the workmanship and finish. Electrical, mechanical and ageing tests have also been included.

METHODS FOR THE SAMPLING AND EXAMINATION OF BITUMINOUS ROAD MIXTURES (B.S. 598.)

A revision of the above British Standard Specification No. 598 has recently been issued as the experience gained since the first issue in 1936 has shown that a number of modifications were desirable in order to keep it up to date with present practice.

In the new issue certain sections have been completely revised, other main features are the inclusion of a modified test for the rapid determination of bitumen content and two alternative methods for the recovery of bitumen. The two latter methods are recommended as tentative methods, and it is hoped that the experience obtained by industry will enable a decision to be made at a later date as to whether one or both of these methods should be adopted as British Standards.

Tests on mineral aggregate have been deleted as these are now provided for in B.S. 812, Sampling and Testing of Mineral Aggregate, Sands and Fillers.

Attention of members is invited to the following more important British Standard A.R.P. Specifications:—

BS-ARP No. 16. (First Revision) Methods of providing low values of Illumination (not exceeding 0·002 Foot-Candle).

BS-ARP No. 36. Headlamp marks for Road Vehicles.

BS-ARP No. 54. Electrical Heating of Shelters.

BS-ARP No. 53. Detection of Incendiary Bomb Fires by Heat-Sensitive Devices.

The following Specifications have been cancelled:—

BS-ARP No. 24 Hydrabed Lime.

BS-ARP No. 25. Lime-Cement Mortar.

Copies of all these British Standards can be obtained from:—

Messrs. Thacker & Co., Ltd.,
P. O. No. 120, Bombay.

Messrs. Thacker Spink & Co. (1933) Ltd.,
3, Esplanade East, Calcutta.

Messrs. Higginbothams,
P. O. Box 311, Madras.

The undermentioned draft Specifications, have been forwarded by the British Standards Institution for comments.

C. F. (ME) 7186. The Dimension of Drilling Jig Bushes.

C. F. (NF) 7338. Cast Brass Bars (suitable for forging) and forging.

C. F. (EL) 7258. Laminated Synthetic Resine Bonded sheet (Fabric Base).

C. F. (IS) 7422. Proposed Addendum Slip to B.S. 786. High Duty Iron Castings providing for a Grade 4.

C. F. (CM) 7410. Studio Spot Light Lamps and Associated Equipment.

C. F. (CM) 7518. Excitor Lamps for 35 mm. Projectors.

C. F. (TIB) 7468. Grading Rules for Structural and Carcassing Timber.

C. F. (IS) 7723. War Emergency Specification for High Tensile (Fusion Welding Quality) Structural Steel for Bridges, etc. and General Building Construction.

C. F. (ME) 7708. Engineers' Comparators (for External Measurement).

NOTICE.

Following notice has been issued by the Federal Public Service Commission.

In accordance with the decision of the Government of India (Railway and Labour Departments) candidates for the Indian Railway Service of Engineers and Central Engineering Service, Class I, joint examinations will, with effect from the examination to be held in 1941, be required to produce a certificate stating that they have undergone a practical course of Surveying equivalent to that given in the full course for a Degree or Diploma in Civil Engineering.

SUBJECT INDEX*

TO

JOURNAL VOLUMES I TO XXI No. 1.

* An index arranged according to Authors, appeared in Vol. XXI—No. 1

1. The Title of this paper in Index of Vol. XXI—No. 1 was incorrectly printed.
2. The Title of this paper in Index of Vol. XXI—No. 1 was left incomplete.

150

THE JOURNAL

OF

The Institution of Engineers (India).

Vol. XXI December, 1941. No. 3

Journal Committee

The President

P. F. Colvala,

A. R. Nisser,

Tech. Secy.

The Institution of Engineers (India) as a body accept no responsibility for the statements made in the Journal

Correspondence on all controversial matters is invited and will be published in the journal if approved by the Journal Committee

This issue 1700 Copies.

CONTENTS

Address all Communications to—

A. R. NISSER, E. E. Hons. (U. S. A.), D. I. C. (London)

Technical Secretary

THE INSTITUTION OF ENGINEERS (INDIA).

Telegrams "ENJOINE" 8, Gokhale Road, Calcutta.

THE INSTITUTION OF ENGINEERS (INDIA).

To the Members of the Bombay Centre.

Our Technical Secretary has asked me to write an appeal to you all, to muster in strength at our Annual Meeting at Bangalore in January 1942. In making the appeal I urge that, one of the objects of our Institution is the diffusion of knowledge. This can be achieved by personal contact and exchange of experiences. Our General Meetings offer opportunities for this. And this will help you to realize the gravity and seriousness of the world crisis, through which we are passing and the importance of our work in solving some of the problems which the war is leaving in its wake. Your Council and Committee are engaged on considerations of production for the war, on improving the education and status of the Engineer, in revising our Bye-laws, in arranging exchange of privileges with foreign Institutions, in influencing Government and other Bodies to accord better treatment to the Engineer, in helping to visualize and prepare for post war conditions and many other important subjects. You can help by your presence, by taking part in the discussions and influencing your delegates in the Council and Committees.

Come and you will be welcomed by our hosts of the Mysore Centre, who are doing so much to make your visit instructive and entertaining.

(Sd.) R. K. Nariman,

Chairman, Bombay Centre.

To the Members of the Hyderabad Centre.

The Twenty-second Annual General Meeting of the Institution of Engineers (India) is going to be held during January 1942 at Bangalore, the Capital of Mysore, and the hub of the industrial activity of the most progressive State in India. Bangalore known as the tourists' paradise is an attraction even for the layman. The garden layout of the city and its bracing climat have given Bangalore the sobriquet of the garden of Souther India. The State holds numerous works of Engineering intere which are well worth a visit. Indeed it is difficult to find els where in India so many works within so short a range of com pass. Notable amongst these are the Kolar Gold fields, th Sivasamudram Falls and Power Station, the Mandya Su Factory, the Krishnarajasagar Dam and its enchanting Brin van Gardens. Further afield are the the Bhadravati Iron Wo

TELEGRAM

O OL BANGALORE A 2 410 ENJOIND

CALCUTTA .

FROM CONSIDERATIONS OF CLIMATE AND ALSO INDUSTRIAL ADVANCEMENT I INVITE EVERY MEMBER OF THE INSTITUTION TO ATTEND THE BANGALORE SESSION AND I DO HOPE THAT THEY WILL MUSTER STRONG AND MAKE IT AN UNPRECEDENTED SUCCESS.

GANESH AIYER
Chairman,
Mysore Centre.

An open invitation from Mr. Ganesh Aiyer, Chairman, Mysore Centre, to all members.

the Mysore Paper Mills and the famous Jog Falls Hydro-Electric Project under construction Bangalore itself has got several industrial concerns which merit a visit from our Engineers, particularly in view of the fact that they more than anyone else, shall have to be closely associated in future with the Industrial Reconstruction of India

Hyderabad as the next door neighbour of Mysore, feels justified in strongly supporting the warm invitation from the Engineers of Mysore for a visit to their progressive land It is hoped that Engineers from all parts of India would make a point of attending the Session

(Sd) Syed Ali Raza,

Chairman, Hyderabad Centre

To the Members of the U P Centre

The next Annual General Meeting of the Institution is to be held about the middle of January, 1942 in Bangalore I would request you to try your best to attend the Annual General Meeting and have a good opportunity of meeting many members of the Institution from different parts of India and take active part in the deliberation in the meeting and also in the visits of many important and interesting Engineering concerns.

Members of Northern India will have a good opportunity on this occasion of inspecting many historical places in the Southern part of this great peninsula, if they so desire I consider the Brindaban Gardens at Mysore, one of the most gorgeous sights I have ever seen anywhere in the world

(Sd) Mahabir Prasad.

Chairman U P Centre

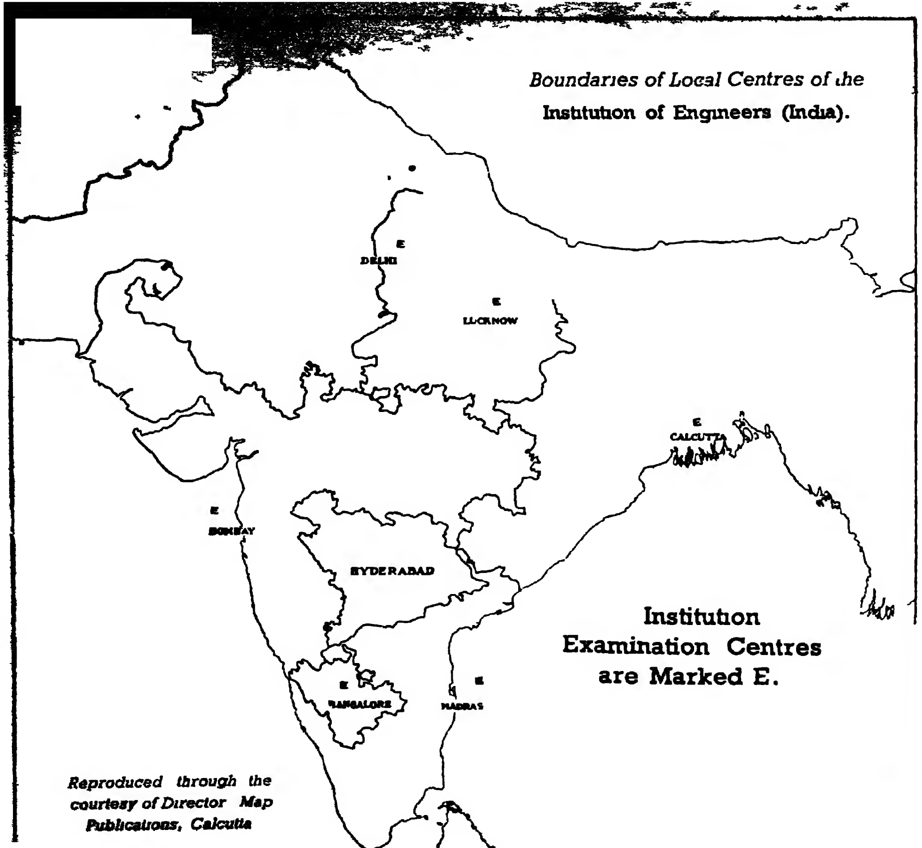
To the Members of the South India Centre.

Gentlemen :— The next Annual General Conference of our Institution will be held at Bangalore towards the beginning of the coming year May I appeal to you all to come forward and attend in large numbers with a view to make the conference an unique and complete success

Yours sincerely,

(Sd) B. S Chetti.

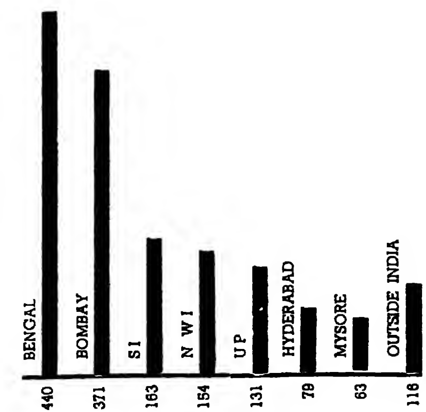
Chairman, South India Centre



Reproduced through the courtesy of Director Map Publications, Calcutta

DO THESE FIGURES INTEREST YOU ?

Membership of American Engineering Societies in 1940 was as follows—	
American Society of Civil Engineers	16271
American Institute of Mining & Met Engrs	10636
American Society of Mechanical Engrs	14846
American Institute of Electrical Engineers	17891
Society for the Promotion of Engineering Education	3237
American Society of Chemical Engineers	2490
National Council of State Board of Engineering Examiners	233
Total membership of all branches of Engineering	65604
The membership of this Institution comprising all branches is only	1517



MEMBERSHIP
Corrected to 31-8-41

AN ANALYSIS OF THE INSTITUTION PAPERS.

The first volume of the Journal was published in 1921. The current Volume No 21 is published in revised form on a quarterly basis

Altogether 109 papers have been published in the 21 volumes including Volume XXI, No 2

Their analysis is as follows —

On Civil Engineering	subjects	63	papers	or 57 8%
Mechanical ,,	,,	24		or 22%
Electrical ,,	,,	9		or 8 2%
Sanitary ,,	,	7		or 6 3%
Education ,,	,,	2		or 1 84%
Miscellaneous		4		or 3 66%

These papers were presented by 79 members and non-members as follows —

Members	49	or 62 0%
Associate-Members	18	22 8%
Students	2	2 5%
Companions	3	3 8%
Non-Members	7	8 9%

It is evident from this list that papers on several branches of engineering have not been presented at all before the Institution This information has been prepared to stimulate that interest

T S.

THE ABILITIES OF RAILWAY GIRDER BRIDGES*

BY

C. I. STABLER,[1] *Member*

Synopsis.

The Paper describes a system of recording the strength of Railway Girder Bridges, whereby the effect of any particular locomotive on the various members of the girders can be ascertained easily and rapidly.

The system consists in plotting the various uniformly distributed loads which will induce the maximum permissible stress in each individual member of all the different types of spans on the Railway, and comparing the resulting graph with the graph of the Equivalent Uniformly Distributed Load for the engine it is proposed to run. Separate graphs for Shear and Bending are made for each class of engine and for each type of girder.

The Paper describes the meaning of the term "Ability" of a span as the Uniformly Distributed Load in tons per foot which, combined with Impact and Dead Load, will stress any particular member under consideration to the full permissible limit, the Live Load being taken as in that position in which the stress produced by it in the member under consideration will be a maximum.

Special methods, aiming at ease and rapidity in the calculation of the Equivalent Uniformly Distributed Load for Shear and Bending have been devised, and actual examples worked out.

In the case of triangulated spans, formulae and tables of Constants, giving the "Ability" of each member in terms of a Uniformly Distributed Load, have been worked out, and examples of the working both for triangulated and plate spans, are given. The mathematical derivation of the Constants is given in an Appendix.

An example of an "Ability of Section" graph is given, in which the ability of the weakest member of every girder on the section of line is plotted. From this graph the Engineer can tell, at a glance, which girders, if any, will be overstressed by a particular locomotive. He can then refer to the detailed graphs of these girders and ascertain which members will suffer overstress, and to what extent.

Finally, the Paper describes the method by which the maximum permissible speed of an engine may be arrived at, if it is found that the engine would induce overstress when run at unrestricted speed.

A drawing of a "Viewing Box", by means of which comparison of graphs is greatly facilitated, is given.

One of the most important functions of a Railway Bridge Engineer is the certification of the bridges on his Railway as

*An Institution Paper.

1. Bridge Engineer, B. N. Ry., Calcutta.

Note:—Written comments are invited for publication.

safe or otherwise for the passage of any locomotive or vehicle which the Transportation Department may propose to run.

On an old Railway, on which the Bridges have been designed to a variety of specific loadings, impact factors, and permissible stresses, it is never easy to say, with any degree of mathematical certainty, whether or not the introduction of a new type of engine, or the running of an unusually heavily loaded wagon will induce excessive stresses in some or possibly all of the girders.

As a rule, a reply to the query is wanted quickly, and there is rarely, if ever, time to work out the stresses which will be induced in the girders on the section concerned by the ordinary methods of structural mechanics. More often than not the best that can be done in the time available is to compare the proposed load with the loads which the girders on the section are carrying and have carried in the past.

As loads and speeds increase, however, mere comparison with existing loads becomes increasingly misleading. It becomes necessary to devise some method whereby the information obtained is more reliable, but which at the same time will be available easily, quickly, and without involving long and tedious calculations.

The system described in this paper is now in use on the Bengal Nagpur Railway, and it has been found to fulfill these requirements.

By its use it is possible to say, at a glance, whether any proposed load will induce overstress in any of the Bridges in any particular section of the Railway, which bridges will suffer overstress, and which members of such bridges will be overstressed.

Stated very briefly, the system consists in plotting the various uniformly distributed loads which will induce the maximum permissible stresses in each individual member of all the different types of spans on the Line, and comparing the resulting graph with the graph of the Equivalent Uniformly Distributed Load (E.U.D.L.) for the engine it is proposed to run. Separate graphs for Shear and Bending are made for each class of engine, and for each type of girder.

The calculations necessary for the compilation of the graphs took a considerable time to complete, but methods

were devised which reduced the work considerably and it was arranged in such a manner that a large part of it could be carried out by Computors with no special technical knowledge.

The first operation was to draw the E.U.D.L. graphs for Shear and Bending for every type of engine on the Railway. The methods adopted in this work are given below.

Calculation of Equivalent Uniformly Distributed Load.

(1) ***Bending Moment.***—For spans under 80 feet in length, the E.U.D.L. may be found by equating the amount of the Bending Moment at the centre (the load having been taken as in that position which will produce the greatest Bending Moment at the centre) to the Bending Moment at the centre produced by an evenly distributed load.

Thus, if M=the Maximum Bending Moment at the centre due to a particular engine and following load.

W=Equivalent load per ft. run.

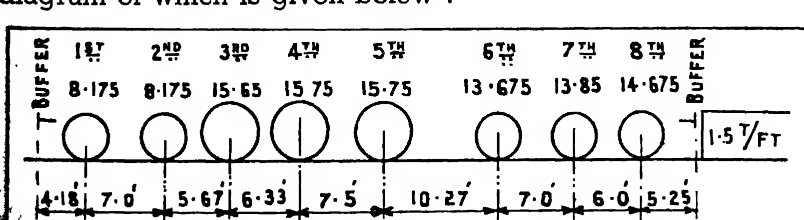
l=Span in feet.

then $M = \frac{W l^2}{8}$, whence $W = \frac{8 M}{l^2}$

This, of course, is not strictly accurate, because the parabola formed by the Bending Moment Curve for a uniformly distributed load would not envelope all the points of maximum bending moment drawn for the moving loads. But in small spans the error is negligible.

The first operation is the preparation of a "Moment Table" of the engine from the engine diagram. These "Moment Tables" each consist of three separate parts. The first is for use when the leading wheel is on the span, the second when the leading wheel has moved off the span and the third when two leading wheels are off the span.

Take the B. N. Railway "G.M." Class engine, a wheel diagram of which is given below :—



The "Moment Table" for B.N.R. "G.M." class engine would be as follows :—

	1st Axle.	2nd Axle.	3rd Axle.	4th Axle.	5th Axle.	6th Axle.	7th Axle	8th Axle.	Buffer.	Remarks.
Moment	..	57·23	149 93	352 49	710·62	1362 77	1903·01	2449·16	3004 08	
Weights	..	16·35	32 00	47·75	63 50	77·18	91 03	105 70	105 70	Part I.
Distance	..	7·00	12·67	19 00	26 50	36 77	43·77	49·77	55·02	
Moment	..	..	46·35	196·16	493 98	1002·17	1545 18	2042·28	2554 28	
Weights	..	..	23 83	39·58	55 33	69 01	82·86	97 53	97·53	Part II.
Distance	..	..	5·67	12·00	19 50	29 77	36 77	42 77	48·02	
Moment	..	..	..	99 05	334 5	818 80	1244 59	1692 63	2161 71	
Weights	..	..	..	31·40	47 15	60 83	74 68	89·35	89 35	Part III.
Distance	..	..	..	6·33	13 83	24·10	31·10	37·10	42 35	

A moment's scrutiny of the Table will show that they are not difficult to prepare.

Consider Part I of the above Table.

Opposite "Distance", the figure 7·00 appears in the column headed "2nd axle", and it is the distance from the 1st axle to the 2nd axle. In the "3rd axle" column, is 12·67, which is the distance from that axle to the 1st axle. Under "4th axle" is placed the distance from the 4th to the 1st axle, and so on. Similarly, opposite "Weights" is written the total weight of all the axles preceding and including the axle whose number heads the column. Thus under "5th axle" is written the weight of the 1st + 2nd + 3rd + 4th + 5th axles. Opposite "Moment", the figure 57·23 is the moment of the 1st axle about the 2nd, i.e. 8·175 × 7·00. The figure 149·93 is the moment of the 1st + the 2nd axles about the 3rd, or 57·23 + (8·175 + 8·175 × 5·67). The moment at the 8th axle, for instance, is obtained by multiplying the weight up to and including the 7th axle (=91·03) by the distance between the 7th and 8th axles (=6·00) and adding the moment up to the 7th axle (=1903·01). Thus it will be seen that any moderately good arithmatician can perform all the necessary calculations. The Table may be entered in a foolscap book, the engine diagram being drawn (to scale) on the left hand page, with the Relative Moment Table facing it on the right hand page.

Having prepared the Moment Table, the position of Maximum Bending Moment is found as follows :—

The Maximum Bending Moment in a span loaded with concentrated loads must occur at one of the loads, and that load must be somewhere near the centre of the span, and it must be a load near the centre of gravity of the system of loads on the span.

We therefore place several loads in turn at the centre, and calculate the Bending Moment in each case—choosing the Maximum finally.

Take the case of a "G.M." Class engine, whose Diagram and Moment Table appear on pages 531 & 532, on a 42 foot effective span.

On the edge of a strip of paper, the span, 42 feet is marked off to the same scale as the engine diagram, and on it the centre of the span is marked. The strip is then placed under the diagram, placing each axle in turn at the centre. By scrutiny of the disposition of the loads on the span and their respective magnitudes, some idea can be formed as to the probable position in which the Bending Moment at the centre will be a Maximum. In the case under consideration, for instance, it would appear probable that the Bending Moment at the centre would be a maximum when the 4th axle is at the centre. In this position all the heavy driving wheels are in the vicinity of the centre, both the leading bogey wheels are still on the span, and one of the comparatively heavy tender wheels has entered the span.

When the 4th axle is at the centre, the leading wheel is still on the span, hence the figures for our calculations must be taken from Part I of the Moment Table. The strip also shows that the 6th axle will be on the span but that the 7th will not.

The reaction at the leading end of the span will be equal to the Moment of the 1st and succeeding axles about the 6th axle, plus the combined weight of all the axles from the 1st to the 6th inclusive multiplied by the distance of the 6th axle from the trailing end of the span, divided by the total length of the span.

All the figures except one required to perform this calculation are given in the Moment Table. The only figure we have to ascertain is the distance of the 6th axle from the trailing end of the span.

The distance from the 1st axle to the centre of the span (*i.e.*, from 1st to 4th axle) is given in the Table as 19·00 feet, while the distance between the 1st and 6th axle is 36·77 feet. Hence the distance from the 6th axle to the trailing end of the span is $19 + \frac{42}{2} - 36{\cdot}77 = 3{\cdot}23$ feet.

Reading from the Moment Table the other figures required are :

(1) Moment of 1st and succeeding axles about 6th=1362·77 ft. tons.

(2) Combined weight of 1st to 6th axle inclusive=77·18 tons.

The reaction at the leading end of the span can therefore be written :—

$$\frac{1362 \cdot 77 + (77 \cdot 18 \times 3 \cdot 23)}{42}$$

and the Bending Moment at the centre is equal to

$$\left\{ \frac{1362 \cdot 77 + (77 \cdot 18 \times 3 \cdot 23)}{42} \times 21 \right\} - 352 \cdot 49 = 453 \cdot 5\ 4 \text{ft. tons.}$$

(The figure 352·49 is the Moment of the 1st + 2nd+3rd axles about the 4th, *vide* the Moment Table).

It will be seen with what ease the moments, weights and distances can be read directly from the Table.

In the above calculation, the moments, etc. have been taken from Part I of the Moment Table, because, when the 4th axle is placed on the centre of the span, the leading wheels are also still on the span. Had the leading wheels been off the span, then Part II of the Table would have been used, and had the position of the engine been such that axles No. 1 and 2 were off the span, then the moments, weights and distances would have been read from Part III.

A fourth table could be prepared, of course, for cases in which axles No. 1, 2 & 3 are clear of the span, but experience has shown that cases in which the Maximum Bending Moment occurs with the engine in such a position are so rare that the preparation of a fourth table is not warranted.

The Bending Moment when the 4th axle is at the centre of the span has been found above. It is now necessary to place other axles at the centre, and choose that position which produces the greatest Bending Moment. If the 3rd and 5th axles each produce smaller Bending Moments than does the 4th, then we know that our original choice of axle was correct.

Try the 3rd axle at the centre. The trailing end of the span will be $\frac{42}{2} + 12 \cdot 67 = 33 \cdot 67$ feet from the 1st axle, and there will be five axles on the span.

Reading from the Moment Table, Bending Moment at the centre in this case will be :—

$$\left(\frac{710\cdot62 + 63\cdot50\ (33\cdot67 - 26\cdot50)}{42} \times 21\right) - 149\cdot93 = 433\cdot03$$

Try the 5th axle at the centre.

In this case, the leading axle will be off the span, so readings must be taken from Part II of the Table.

The trailing end of the span will be $\frac{42}{2}+19\cdot5=40\cdot50$ feet from the 2nd axle, and there will be six wheels on the span—that is the 7th axle will be on the span.

Then reading from Part II of the Moment Table the Bending Moment will be :—

$$\left(\frac{1545\cdot18+82\cdot86\ (40\cdot50-36\cdot77)}{42} \times 21\right) - 493\cdot98=433\cdot14.$$

The maximum of the three trials is the first *i.e.* when the 4th axle is over the centre of the span. It is obvious that further trials are unnecessary, as the Bending Moment would decrease as the engine passed further over the span. If the 6th axle were placed at the centre, for instance, one of the drivers would be off the span. Very little practice is necessary to enable one to say which axle when placed at the centre, will probably produce the Maximum Bending Moment. If the engine diagrams are drawn to scale, judgment in this respect is materially assisted, and more than three trials are rarely necessary.

From the above, then, it is seen that the Maximum Bending Moment, amounting to 453·54 ft. tons, occurs when the 4th wheel is at the centre.

Now if W = E.U.D.L. for Bending Moment,

then $\frac{WL^2}{8}$ = Bending Moment = 453·54

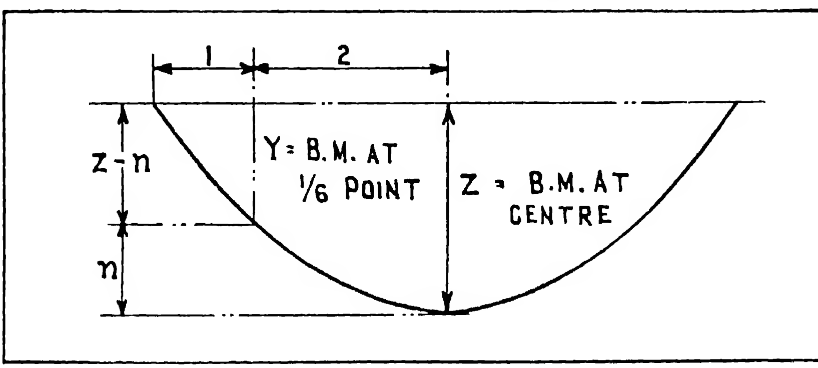
whence $W = \frac{8 \times 453\cdot54}{42 \times 42} = 2\cdot06$ tons per ft. which is the Equivalent Uniformly Distributed Load for Bending for a "G.M" Class engine on 42 ft. effective span.

The process is the same for any length of span, except that, for spans over 80 feet in length, the Maximum Bending

Moment is found at the $\frac{1}{6}$ point, and from this the Bending Moment at the centre obtained.

By so doing the Bending Moment obtained at the centre may be slightly in excess of the actual maximum, but a parabolic curve drawn through a centre point obtained in this manner will envelope all the points on the actual Maximum Bending Moment curve for the moving loads.

If the enveloping curve is assumed to be parabolic, then the value of the Bending Moment Z at the centre will be 1·8 times the Bending Moment Y at the $\frac{1}{6}$ point, and W the E.U.D.L. for Bending Moment will be 14·4 Y/L^2, thus :—



The curve is of the form $Y = MX^2$

$z = M \times 3^2$

$n = M \times 2^2$

$$\therefore \quad \frac{z}{z-n} = \frac{Z}{Y} = \frac{M \times 3^2}{(M \times 3^2) - (M \times 2^2)} = \frac{9M}{5M} = \frac{9}{5}$$

$$\therefore \quad z = \frac{9\,Y}{5} = 1{\cdot}8\,Y$$

$$1{\cdot}8 \quad Y = \text{Bending Moment at centre} = \frac{WL^2}{8}$$

whence $W = 14{\cdot}4 \quad Y/L^2$

The following shows how the E.U.D.L. for Bending Moment for a B. N. R. Class "G.M" engine is obtained for spans over 80 feet in length :—

Calculation of E.U.D.L. for Bending Moment for Spans over 80′ in length.

Loading — "G.M" Class followed by 1·5 tons per foot.

Span — 300 feet.

$\frac{1}{6}$ th of span = 50 feet, and 300 − 50 = 250 feet.

Try 5th Axle at $\frac{1}{6}$th point.—As all axles will be on the span, Part I of the Moment Table must be used.

		Feet.
Distance from 5th Axle (= $\frac{1}{6}$ th Point) to trailing end of span	=	250·00
Distance from 5th Axle to 1st Axle (from Table)	=	26·50
Distance from 1st Axle to trailing end of span	=	276·50
Distance from 1st Axle to trailing buffer (from table)	=	55·02
Then length covered by following (distributed) load	=	221·48 Ft.

Y = Bending Moment at $\frac{1}{6}$ th point.

Then, reading Moments and Weights from the table,

$$Y \text{ for the engine only} = \left(\frac{3004{\cdot}08 + (105{\cdot}70 \times 221{\cdot}48)}{300} \times 50\right) - 710{\cdot}62$$

But to this must be added the Bending Moment due to the following load of 1·5 tons per foot, thus making the total Bending Moment at the $\frac{1}{6}$ th point

$$= \left(\frac{3004{\cdot}08 + (105{\cdot}70 \times 221{\cdot}48) + \dfrac{(1{\cdot}5 \times 221{\cdot}48^2)}{2}}{300} \times 50\right) - 710{\cdot}62$$

$$= 9816{\cdot}80 \text{ ft. ton.}$$

Further trials, with other wheels at the sixth point, will show that the maximum value in this particular case is obtained when the 5th axle is at the sixth point.

$$\text{Then W, the E.U.D.L. for Bending Moment} = 14{\cdot}4 \times \frac{9816{\cdot}8}{300 \times 300}$$

$$= 1{\cdot}57 \text{ tons per ft. run.}$$

In this manner the E.U.D.L's for Bending Moment for each type of engine on the line are calculated. When written out at length as above, the work appears formidable, but the actual calculations are not, of course, written out in such detail.

Once the length covered by the following load has been ascertained, the Bending Moment can be written out in one line.

As the calculations are completed for each engine, the results are plotted on Tracing Cloth. The E.U.D.L. graph for Bending Moments for a B.N.R. Class "G.M" engine is shown in Plate I. (see page 556).

(2) ***Shear.***—The same Moment Table is used in the calculation of Shear E.U.D.L. but, unless there is considerable difference between the weights of the respective driving

wheels, the maximum Shear effect usually occurs when the leading driving wheel is over one end of the Span. Hence, in the case of an engine with neither Bissel wheels nor leading bogey, Part I of the Table is used ; for an engine with a Bissel wheel, Part II is used, and for an engine with a leading bogey, as in the case of the B.N.R. Class "G.M" engine Part III of the table is used.

If M = The Moment (vide Moment Table) about the last wheel or trailing buffer on the span.

E = Total weight (vide Moment Table) of all the engine wheels on the span.

L = Total length of span in feet.

d = Distance in feet from 1st to the last wheel or trailing engine buffer on span (vide Moment Table.)

then when one wheel is over the leading end of the Span, the reaction (or end Shear) at that end.

$$= \frac{M + E(L - d)}{L}$$

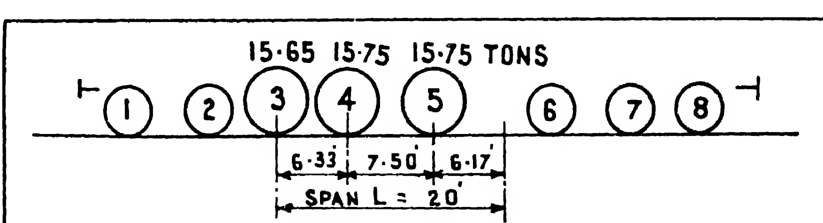
In the case of a beam carrying a uniformly distributed load of W tons per ft., the end Shear is $\frac{WL}{2}$

Then $\frac{WL}{2} = \frac{M + E(L - d)}{L}$

Whence W, the E.U.D.L. for Shear $= \frac{2}{L^2}\left\{M + E(L - d)\right\}$

Take the case of a 20′—0″ Span loaded with a "G. M." Class Engine.

The maximum shear will evidently occur when the leading driving wheel is over the end of the span, *i.e.* when the leading wheels are off the Span, thus :—



The two leading wheels being off the Span, Part III of the Moment Table must be used, from which we get—

$$W = \frac{2}{20 \times 20}\left\{334{\cdot}57 + 47{\cdot}15\,(20 - 13{\cdot}83)\right\} = 3{\cdot}13 \text{ tons}$$

which is the E.U.D.L. for Shear for a "G.M" Class engine on a 20 foot Span. When the Span is of such a length that it can accommodate the engine and some of the following load, the formula becomes—

$$W = \frac{2}{L^2}\left\{ M + (L-d)\left(\frac{E + w(L-d)}{2}\right)\right\}$$

w being the weight per foot run of the following load and other symbols being as before.

Following is the calculation of the E.U.D.L. for Shear for a "G.M." Class engine on a 60 foot Span.

In this case, a portion of the following load will be on the Span when the 3rd axle is at the leading end of the Span.

"w", the weight per foot run of the following load is 1·5 tons. "d", the distance between the wheel at the leading end of the Span and the trailing engine buffer, is shown as 42·35 in the Moment Table (Part III).
"M", the moment of the 3rd to 8th axle inclusive about the trailing buffer is given as 2161·71, while "E", the total weight of all the engine axles on the Span, is 89·35 tons.

"L" is 60 feet.

W, the E.U.D.L. for Shear, is therefore

$$\frac{2}{60 \times 60}\left\{ 2161{\cdot}71 + (60 - 42{\cdot}35)\, 89{\cdot}35 + \frac{1{\cdot}5\,(60 - 42{\cdot}35)}{2}\right\}$$

$= 2{\cdot}21$ tons per foot.

The results obtained for each engine are plotted on tracing cloth, as shown in Plate 2.

The next operation is to ascertain the "abilities" of the girders in Bending and Shear. The term "abilities" means the uniformly distributed load in tons per foot which, combined with Impact and the Dead Load of the Span, will stress any particular member under consideration to the full permissible limit, the uniformly distributed load (or in other words the Live Load) being taken as in that position on the span in which the stress induced by it in the member under consideration will be a maximum. Special methods have been devised for Triangulated Spans as described below :—

Tables of constants have been worked out for Through and Deck Spans. These Tables are shown in Appendix I, which also give the mathematical derivation of the constants. Briefly,

the process consists in equating the Dead Load plus Live Load plus Impact effects to Af, *i.e.* to the cross Sectional area of the member times the permissible stress per square inch.

The tables of constants are divided into two parts, the left hand for Dead Load effects and the right hand for Live Load. The tables bear a diagram in which each post diagonal end boom member is numbered. The meanings of the Symbols used are given in a tablet in each Table. Thus, take for example the post, diagonal and booms marked 3 in a through span of 10 bays :—

According to the Table of constants, the Live and Dead Load effects will be as follows :—

Member	*Dead Load Effect*	*Live Load Effect (Including Impact)*
Post 3.	$11 \times D / 120$	$42 \times \frac{a. I. p}{40}$ or $\frac{12 \times a. I. p}{40}$ (Reverse Loading)
Diagonal 3.	$-9 \times D / 120 \times \frac{1}{h}$	$-42 \times \frac{a. I. p}{40} \times \frac{1}{h}$ Or $12 \times \frac{a. I. p}{40} \times \frac{1}{h}$ (Reverse Loading)
Boom 3.	$63 \times D / 120 \times \frac{p}{h}$	$21 \times \frac{a. I. p}{4} \times \frac{p}{h}$

The Dead Load and Live Load plus Impact effects are added, and, in the case of the member itself are equated to the cross sectional area multiplied by the permissible stress, while for the connections, the combined effects are equated to the rivet ability of the connection. "a" the ability of the member in terms of tons per foot run on the loaded length of Span is thus obtained.

Where reversal of stress occurs, the ability equation has to be modified on the principle that—

Area $\times$ permissible stress = (Direct Loading) + (Half the Reverse Loading) = (Dead Load + Live Load) + $\frac{1}{2}$ (Reverse Live Load — Dead Load)

$$= \tfrac{1}{2}\,DL + LL + \tfrac{1}{2}\,R.$$

To obtain the Reverse Loading effect, the factors in the right hand table between the horizontal lines of factors for Posts and Diagonals are used. It is further necessary, however, to apply a correction factor which represents the ratio of the

load per foot run for reversal over the load per foot run for direct loading. For convenience, the factor is given the symbol "S".

The factor "S" must be fixed with reference to the Standard of load which approximates to the standard which we know the Span is capable of carrying.

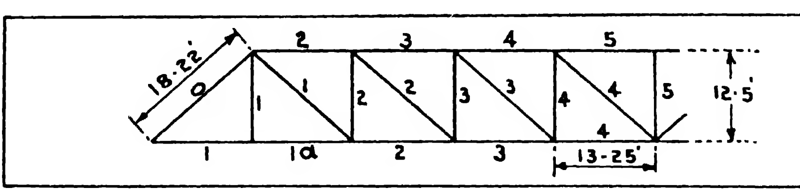
For instance, if the Span had been designed to B.L. Standard of Loading, this standard would be used in arriving at the value of "S". For the 5th diagonal of a 150 foot span of 12 bays, the loaded lengths are 78 feet direct and 62·40 feet reversal, the corresponding BL Standard Loading for Shear being 2·472 and 2·616 tons per foot respectively. Hence "S" for the 5th diagonal of this Span would be $\frac{2 \cdot 616}{2 \cdot 472} = 1 \cdot 06$

Perhaps the best method of showing how the constants are applied, and how the work is arranged is to give an actual example.

The working is done in a foolscap book. First the details of the Span are given, thus :—

125′0″ Through Span.

C.E.'s Type No. 8026.



Effective Span = 132·5′ (Impact + Unity = 1·366)

h = 12·5′

p = 13·25′ — (10 No.)

l = 18·22′

This is followed by the determination of the various factors required in the application of the Table of Constants, thus :—

$$\frac{l}{h} = \frac{18 \cdot 22'}{12 \cdot 5'} = 1 \cdot 458 \qquad \frac{Ip}{4} = \frac{1 \cdot 366 \times 13 \cdot 25}{4} = 4 \cdot 525$$

$$\frac{p}{h} = \frac{13 \cdot 25}{12 \cdot 5} = 1 \cdot 06 \qquad \frac{Ip}{4} \times \frac{p}{h} = 4 \cdot 525 \times 1 \cdot 06 = 4 \cdot 797$$

Weight of Span = 139·66 tons

Permanent Way $= \dfrac{11 \cdot 93 \text{ tons}}{151 \cdot 59 \text{ ,,}}$ $D = 151 \cdot 59$, $\dfrac{D}{120} = \dfrac{151 \cdot 59}{120} = 1 \cdot 263$

$$\frac{D}{120} \times \frac{p}{h} = 1 \cdot 263 \times 1 \cdot 06 = 1 \cdot 339$$

$$\frac{p}{40} = 0 \cdot 331, \quad \frac{p}{40} \times \frac{1}{h} = 0 \cdot 331 \times 1 \cdot 458 = 0 \cdot 483$$

$$\frac{D}{120} \times \frac{1}{h} = 1 \cdot 263 \times 1 \cdot 458 = 1 \cdot 84$$

$$\frac{1}{2}\left(\frac{D}{120} \times \frac{1}{h}\right) = 0 \cdot 92$$

Below, a Table of Loaded Lengths, Impact Factors and Properties is prepared, thus :—

Member 1	Loaded Length. 2		Impact plus Unity. 3	Cross Sectional Area. 4	Permissible Stress. 5	A.f. (4 × 5)
Top Boom	2	132 5	1·366	51·254	7·65	392·09
,, ,,	3	132 5	1·366	51·254	7·65	392·09
,, ,,	4	132 5	1·366	70·004	7·65	535·53
,, ,,	5	132 5	1·366	70 004	7·65	535·53
Bottom Boom	1	132 5	1·366	42·44	9·00	381·96
,, ,,	1a	132 5	1·366	42·44	9·00	381·96
,, ,,	2	132 5	1 366	46·34	9·00	417·06
,, ,,	3	132·5	1·366	53 40	9·00	480·60
,, ,,	4	132 5	1·366	63 41	9·00	570 69
Diagonal	0	119·25	1·396	47·69	7·65	364·83
,,	1	106·00	1·433	26·56	9 00	239·04
,,	2	92 75	1·472	19·35	9·00	174·15
	2	26 50	1·909	...	...	
,,	3	79 50	1 522	14 69	9·00	132·21
	3	(39 75	1·767	...	...	
,,	4	(66 25	1 584	11·60	9·00	104·40
	4	53·00	1·663	...	...	
Post	1	26 50	1 909	14·72	9·00	132·48
,,	2	92 75	1·472	20·76	6·34	131·62
	2	26·50	1·909	...	...	
,,	3	79 50	1·522	16·69	6·03	100·64
	3	39 75	1·767	...	...	
,,	4	66·25	1·584	16·69	6·03	100·64
	4	53·00	1·663	...	...	
,,	5	26·50	1·909	16·69	6·03	100·64

Then follows the actual working out of the abilities of the individual members, in the order in which they are given in the Table. As the working is exactly the same for all the members of each type, only one of each type is given below.

Abilities of Boom.—Boom 2.—From the Tables of Constants,

Dead Load Factor (written DLF) = 48.

Live Load Factor (written LLF) = 16.

and $DLF\ (D/120 \times p/h) + \left(LLF\ \frac{alp}{4} \times \frac{p}{h}\right) = Af = 392.09$ (from Table of Properties above.)

$= (48 \times 1{\cdot}339) + (16 \times 4{\cdot}797 \times a) = 392.09$

$= 64{\cdot}27 + 76{\cdot}75a = 392{\cdot}09$

$a = \frac{327{\cdot}82}{76{\cdot}75} = 4{\cdot}27$ tons per foot.

That is to say, a train could travel at unrestricted speed over the bridge, and, so long as the E.U.D.L. for Bending of the train does not exceed 4·27 tons on a loaded length of 132·5 feet, the material in the top boom in bay No. 2 would not suffer stress greater than the permissible, *i.e.*, 7·65 tons per square inch. The strength of the rivetted connections is investigated in the same manner.

In this particular case, the joint at the end above post No. 2 has fewer rivets in it than the joint at the other end of this section of the boom and is therefore the weakest, and as the strength of the member is limited to the strength of the weakest joint, this joint only need be investigated.

There is a total of 78 rivets in the joint, all in single shear. They are all 1 inch diameter, and, being field rivets, they have a shear value of 4·26 tons each.

The total strength of the joint is therefore 78 × 4·28=333·84 tons.

Therefore, as above, $64{\cdot}27 + 76{\cdot}75a = 333.84$

whence $a = 3{\cdot}51$ tons per foot.

The joint, therefore, is considerably weaker than the member itself, the full strength of which can consequently never be developed unless the rivets are to be overstressed. This is very often found to be the case in old girders.

The abilities of all the other boom members, top and bottom, are found in exactly the same manner.

Abilities of Diagonals.—Since Reversal disappears as the ends of the Span are approached, it is advisable to investigate the web members from the centre outwards. For members subject to Reversal, we have :—

$\frac{1}{2}$ Dead Load + Live Load + $\frac{1}{2}$ Reversal Load = Af.

Hence, according to the Table of Constants—

$$\left(\tfrac{1}{2}\,\text{DLF} \times \frac{\ }{120} \times \frac{\ }{h}\right) + \left(\text{LLF} \times \frac{a.\text{I}.p}{40} \times \frac{1}{h}\right) + \left(\tfrac{1}{2}\,\text{RLF} \times \frac{a.\,\text{Ir}.\,p}{40} \times \frac{1}{h} \times \text{S}\right)$$

$$= \left(\tfrac{1}{2}\,\text{DLF} \times \frac{\text{D}}{120} \times \frac{1}{h}\right) + \left(\frac{p}{40} \times a \times \frac{1}{h}\right) \times \left\{\left(\text{LLF} \times \text{I}\right) + \left(\frac{\text{S}}{2} \times \text{RLF} \times \text{Ir}\right)\right\} = \text{Af.}$$

In this equation RLF means "Reverse Load Factor" and I_r means "Impact on the Reversal Loaded Length". Other symbols have the same meaning as before.

DLF, LLF, RLF, S, I and I_r all vary according to the position of the diagonal under consideration.

Diagonal No. 4.—From the Table of Constants,

DLF	=	3
LLF	=	30
RLF	=	20

and from the Table of Loaded Lengths, etc. on page 542,

Af	=	104·40
I	=	1·584
Ir	=	1·663

In this case the value of "S" was found on the basis of ML Standard Loading.

Thus the loaded length for Direct Loading is 66·25 feet, *vide* the Table on page 542, the E.U.D.L. for ML Standard for Shear for this length being 3·311.

The loaded length for Reversal is 53·00 feet, for which the E.U.D.L. is 3·566.

$$\text{Therefore } S = \frac{3{\cdot}566}{3{\cdot}311} = 1{\cdot}071$$

The above equation then becomes

$$\left(0{\cdot}92 \times 3\right) + 0{\cdot}483a \left\{ \left(30 \times 1{\cdot}584\right) + \frac{1{\cdot}071}{2}\left(20 \times 1{\cdot}663\right) \right\} \quad 104{\cdot}40$$

from which $2{\cdot}76 + 31{\cdot}58a = 104{\cdot}40$

$$a = \frac{101{\cdot}64}{31{\cdot}58} \quad = 3{\cdot}22 \text{ tons per foot.}$$

Rivet Ability.—There are 28 field rivets 1 inch diameter in single shear in each end of the diagonal. Hence the strength of the connection is—

$$28 \times 4{\cdot}28 \;=\; 120{\cdot}0 \text{ tons.}$$

In the case of members subject to Reversal of Stress, the Bridge rules of the Government of India require the end connections to be proportioned for the sum of the stresses due to compression and tension.

Hence the strength of the connection must be equal to
(Direct Loading) + (Reverse Loading)
= (Dead Load + Direct Live Load) + (Reverse Live Load—Dead Load)
= Direct Live Load + Reverse Live Load.

Applying the appropriate factors from the Table of Constants, we have

$$\left(\text{LLF} \times \frac{a.\,I.\,p}{40} \times \frac{1}{h} \right) + \left(\text{RLF} \times \frac{a.\,I_r.\,p}{40} \times \frac{1}{h} \times S \right)$$

which reduces, in this particular case, to

$$40{\cdot}2a = 120$$

from which a (rivets) = 2·98 tons per foot on the loaded length.

In this case the joint is weaker than the member. The permissible load, therefore, is limited to that allowed by the strength of the former, *viz.*, 2·98 tons per foot.

All diagonals are worked out in a similar manner. The calculations for those towards the ends are much simpler due to the fact that there are no complications on account of Reversal.

Abilities of Posts.—Post No. 3—from Table of Constants,

$$\text{DLF} = 11,\ \text{LLF} = 42 \text{ and RLF} = 12.$$

and $\left(\tfrac{1}{2}\,\text{DLF} \times \frac{D}{120} \right) + \left(\text{LLF}\ \frac{a.I\,p}{40} \right) + \left(\text{RLF} \times \frac{a.I_r.p}{40} \times \frac{S}{2} \right) = \text{Af}.$

From the Table of Properties on page 542

$I = 1{\cdot}522,\ I_r = 1{\cdot}767,$ and $\text{Af} = 100{\cdot}64$

"S" based as before on the ML Standard of loading=1·221

Then the formula becomes :—

$$(\tfrac{1}{2} \times 1{\cdot}263 \times 11) + 0{\cdot}331a \left\{ (42 \times 1{\cdot}522) + \frac{1{\cdot}221}{2} (12 \times 1{\cdot}767) \right\} = 100{\cdot}64$$

$\therefore$ from which we get $6{\cdot}95 + 25{\cdot}42a = 100{\cdot}64$

and $a = \dfrac{93{\cdot}69}{25{\cdot}42} = 3{\cdot}68$ tons per foot.

Rivet Ability.—There are 36 field rivets 1 inch diameter in single shear in each end of the post, the value of the connection therefore being $36 \times 4{\cdot}28 = 154{\cdot}08$ tons.

The member being subject to Reversal of Stress, the end connections must be proportioned for the sum of the Tension and Compression Stresses.

Applying the principles given above for the diagonal connections, we have

$$29{\cdot}4a = 154{\cdot}08$$

from which a = 5·25 tons per foot.

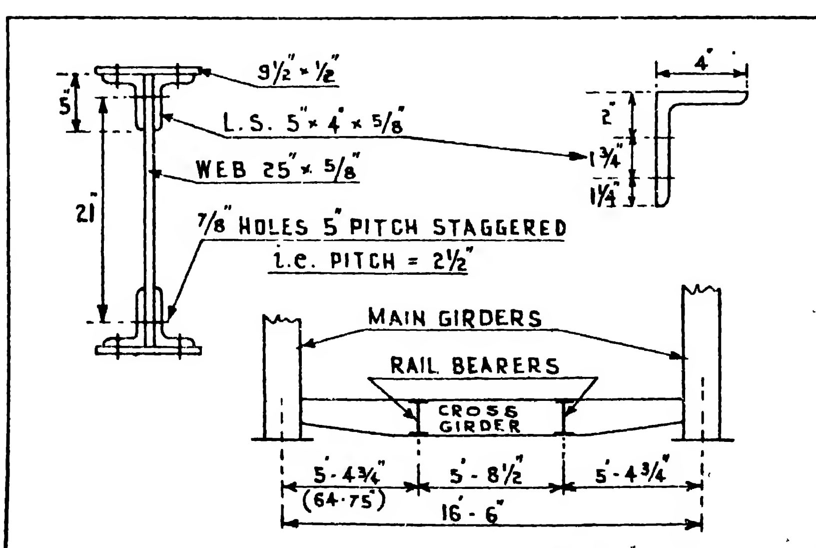
This finishes the calculations for the Main Girders. The abilities of the flooring members remain to be completed. In this particular case the flooring consists of the usual arrangement of cross girders at the panel points, and rail bearers connected to the cross girder webs.

The work is arranged as follows :—

Abilities of Cross Girders (type 8026.)

(i) ***Bending Moment.***—

Cross Section at Centre.



Area of flange = $2\times5{\cdot}236+9{\cdot}5\times\frac{1}{2}$ = 15·222 sq ins.
(Including flange angles)

$\frac{1}{8}$th area of web = $\frac{1}{8}\times25\times\frac{5}{8}$ Gross Area = 1·953 ,, ,,
17·175 ,, ,,

Area of rivet holes in Tension flange = 3·063 ,, ,,
14·112 ,, ,,

Effective depth = $\dfrac{10{\cdot}427\times21{\cdot}78+4{\cdot}75\times25{\cdot}5}{15{\cdot}222}$ = 22·9 ins.

Permissible Stress in Tension = 9 tons per sq. in.

∴ Moment of Resistance = $14{\cdot}112\times9{\cdot}0\times22{\cdot}9$ = 2910·0 in—ton

Panel length = p = 13·25 ft.

Impact plus unity on a loaded length equal to two panel lengths = 1·909

Then maximum Bending Moment on Cross Girder = $\dfrac{1{\cdot}909a\times2p\times64{\cdot}75}{4}$

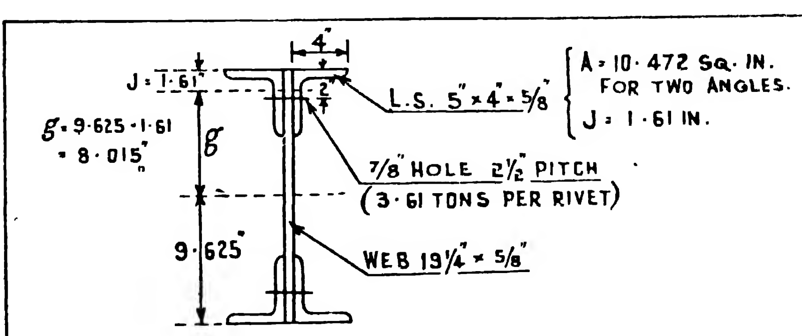
$= \dfrac{1{\cdot}909a\times26{\cdot}50}{4}\times64{\cdot}75 = 817a$, where 'a' = Maximum Permissible Load per ft. run for Bending (in the Cross Girders) on a loaded length equal to the combined length of two successive Rail Bearers.

Maximum Bending Moment = Resisting Moment,

∴ 817a=2910

whence a = 3·56 tons per foot run on the Rail Bearers

(2) *Shear Ability.* ***Section at end.***



The Shear Load = $\dfrac{(\text{Impact}+\text{Unity})\ a\times2p}{4}$

$$= \frac{1{\cdot}909a\times2\times13{\cdot}25}{4} = 12{\cdot}62a$$

Area of flange = 10·472 sq. ins.

$\frac{1}{8}$th area of web = $\frac{1}{8} \times 19{\cdot}25 \times \frac{5}{8}$ = 1·502 sq. ins.

Depth between centres of top and bottom rows of rivets = 13·25 in.

Horizontal shearing force per unit length

$$= \frac{12{\cdot}62.a}{13{\cdot}25} \times \frac{10{\cdot}472}{11{\cdot}974} = 0{\cdot}834a.$$

Strength of $\frac{7}{8}''$ rivet in double shear = 2 × 3·61 = 7·22 tons.

Strength of $\frac{7}{8}''$ rivet in bearing at 15 tons per sq. in.

$$= \frac{7}{8}'' \times \frac{5}{8}'' \times 15{\cdot}0 = 8{\cdot}2 \text{ tons.}$$

Pitch of rivets = 5″ staggered.

$$\therefore \quad 0{\cdot}834a = \frac{7{\cdot}22}{2{\cdot}5}$$

Ability in longitudinal shear = a = 3·46 tons per foot run on a loaded length equal to the length of two consecutive Rail Bearers.

End connection to Rail Bearers = 18 – 1″ diameter field rivets in single shear

Strength of connection = 18×4·28 = 77·0 tons

Resistance of web to shear = 19·25 × $\frac{5}{8}$ × 5·5 = 66·2

The plate, being weaker than the connection, must be accepted as the criterion.

$$\therefore \quad 12{\cdot}62a = 66{\cdot}2$$

whence a, the ability in end shear, = 5·24 tons per foot run on a loaded length equal to the length of two consecutive Rail Bearers.

The rivet values adopted in the above calculation are the Shear values. Had these been greater than the bearing values, the latter would have been adopted.

The ability of the Cross girders, in terms of Load per foot run on the Rail Bearers, is therefore—

Bending Moment	= 3·56 tons
Shear	= 3·46 tons.

Rail bearers are treated in the same manner as Plate girders which is described below.

This finishes the calculations of the abilities of the various parts of the Span and the work is completed by finally entering up a "Table of Abilities" from which graphs for Shear and Bending are made on tracing cloth, as shown in Plates III & IV.

Only the lowest value for each member is plotted, *i.e.*, if the rivetted connection is stronger than the member, the ability of the member is plotted, and *vice versa* if the member is stronger than the connection.

It will be noticed that, in Plates III and IV, the ability of the cross girders appears in the Bending Moment graph (Plate III) only. This is because the load applied to a cross girder through the rail bearers is always the E.U.D.L. for Bending on a loaded length equal to the length of two consecutive rail bearers. Consequently the ability of a cross girder must always be related to the E.U.D.L. for Bending. The E.U.D.L. for Shear on the rail bearers has no meaning so far as the cross girders are concerned.

For cross girders, therefore, the lowest value obtained for Bending, Longitudinal Shear, or End Shear is plotted in the Bending Moment Ability graph for the girder.

The calculation for the abilities of Plate Girder Spans will now be given.

Plate Girders.—In these calculations, the following symbols are used:—

A = Cross sectional area of flange	l = Length of span in inches
J = Distance from heel of section to section to its centre of gravity.	f = Safe fibre stress
I = Moment of Inertia	i = Impact + Unity
D = Dead Load per foot length	R.f = Strength of rivets
Z = Section Modulus	P = Rivet pitch
RM = Resisting Moment	d = Depth
	a = Ability in tons per foot run.

(*i*) ***Bending.***—

The total "ability load" (including Impact) $= \text{i.a.}\dfrac{l}{12}$

Bending Moment due to "ability load" $= \text{i.a.}\dfrac{l}{12} \times \dfrac{l}{8} = \dfrac{\text{i.a.}l^2}{96}$

Total Dead Load $= D \times \dfrac{l}{12}$

Bending Moment due to Dead Load $= D \times \dfrac{l}{12} \times \dfrac{l}{8} = \dfrac{Dl^2}{96}$

If R.M. = the Resisting Moment of one girder, the Resisting Moment of both girders = 2 R.M.

Then $\dfrac{\text{i.a.}l^2}{96} + \dfrac{Dl^2}{96} = 2\text{ R.M.}$

From which "a" for Bending $= \dfrac{\left\{\left(\dfrac{RM}{\frac{l^2}{96}}\right) - \dfrac{D}{2}\right\} \times 2}{i}$ ... (1)

(*ii*) ***Shear.—***

The total "ability load" (including Impact) $= \text{i.a.}\frac{l}{12}$

End Shear due to "ability load" $= \frac{\text{i.a. } l}{12 \times 2}$

Total Dead Load $= D \times \frac{l}{12}$

End Shear due to Dead Load $= \frac{Dl}{12 \times 2}$

Total vertical shear on the span $= \frac{\text{i.a.}l}{24} + \frac{Dl}{24}$

Total vertical shear per Girder $= \frac{\text{i.a.}l}{48} + \frac{D.l.}{48} = V.$

Horizontal shearing force per unit length

$= \frac{V}{d_1} \times \frac{A}{A + \frac{W}{8}}$ where d_1 = depth between centres of top and bottom rows of rivets, and W = area of web.

$$\therefore \frac{V}{d_1} \times \frac{A}{A + \frac{W}{8}} = \frac{Rf}{P} \qquad \ldots \qquad \ldots \qquad (2)$$

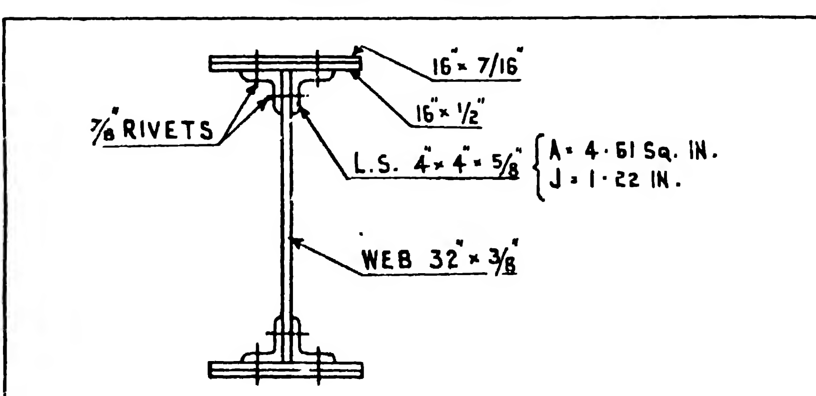
An example is worked out below :—

The entries in the foolscap book begin with the details of the girder, thus :—

40′-0″ span, type 173A
Wrought Iron.

B.M. Ability.

Section at centre.



Effective Span = 42′-0″
i = 1·747

Gross area of Tension Flange $= 2 \times 4{\cdot}61 + 16 \times \frac{15}{16} = 24{\cdot}22$ sq. ins. (The area of the web is neglected, because the web joint is not designed to transmit horizontal stresses.)

Area of Rivet holes $= 2 \times \frac{7}{8} \times \frac{15}{16} + 2 \times \frac{5}{8} \times \frac{7}{8} = 2{\cdot}74$ sq. ins.

Net area of Tension Flange $= 24{\cdot}22 - 2{\cdot}74 = 21{\cdot}48$ sq. ins.

Effective depth $= \dfrac{9{\cdot}22 \times 29{\cdot}56 + 15{\cdot}0 \times 32{\cdot}94}{24{\cdot}22} = 31{\cdot}6$ ins.

Maximum permissible stress in Tension $= 6{\cdot}76$ tons per sq. in.

R.M. = Moment of Resistance $= 21{\cdot}48 \times 6{\cdot}75 \times 31{\cdot}6 = 4570$ inch tons

Weight of span $= 9{\cdot}85$ tons

Weight of span per foot $= 0{\cdot}23$ „

Permanent Way per foot $= 0{\cdot}09$ „

D $= 0{\cdot}32$ „

$$\frac{l^2}{96} = \frac{504 \times 504}{96} = 2646$$

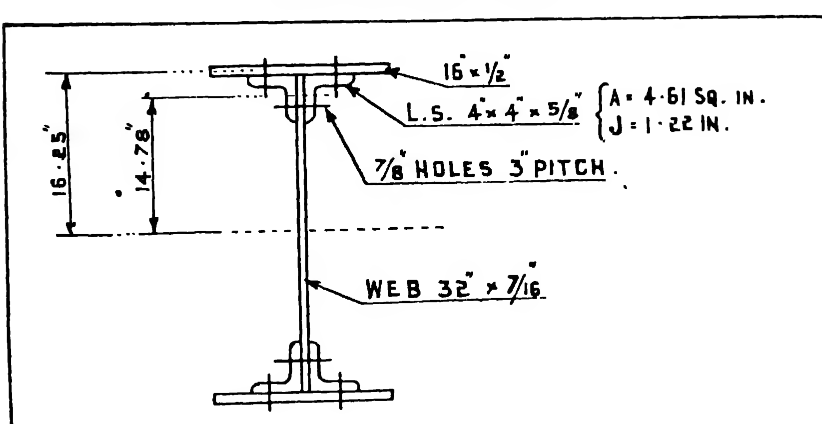
$$\frac{\text{R.M.}}{\frac{l^2}{96}} = \frac{4570}{2646} = 1{\cdot}73$$

Then from equation (1), "a" for Bending Moment $= \dfrac{1{\cdot}73 - 0{\cdot}16}{1{\cdot}747} \times 2$

$= 1{\cdot}79$ tons per ft.

Shear Ability.

Cross Section at end.



"Equivalent depth" by "Burmah Formula" $\dfrac{I}{Ag} = 34{\cdot}94$

Area of flange $= 9{\cdot}22 \times 8{\cdot}0 = 17{\cdot}22$ sq. ins.

1-8th area of web $= \frac{1}{8} \times 32 \times \frac{7}{16} = 1{\cdot}75$ sq. ins.

Total end shear $= \dfrac{1{\cdot}747 \times a \times 42 \times 12}{48} + \dfrac{0{\cdot}32 \times 42 \times 12}{48}$

$= 18{\cdot}35a + 3{\cdot}36$

Depth between centres of top and bottom rows of rivets = 27·5 inches

Horizontal shearing force per unit length

$= \dfrac{18{\cdot}35a + 3{\cdot}36}{27{\cdot}5} \times \dfrac{17{\cdot}22}{18{\cdot}97}$

$= 0{\cdot}606a + 0{\cdot}111$

Strength of $\frac{7}{8}''$ rivet in bearing $= {\cdot}85 \times 15 \times \frac{7}{8} \times \frac{7}{16} = 4{\cdot}88$ tons

Strength of $\frac{7}{8}''$ rivet in double shear $= 0{\cdot}80 \times 2 \times 3{\cdot}61 = 5{\cdot}77$ tons.

Being weakest in bearing, that value must be taken as the criterion of the strength of the rivets.

Pitch of rivets = 3 ins.

then $0{\cdot}606a + 0{\cdot}111 = \dfrac{4{\cdot}88}{3}$

Ability in Longitudinal shear = a = 2·50 tons per ft.

Resistance of web to shear $= 0{\cdot}80 \times 32 \times \frac{7}{16} \times 5{\cdot}5 = 61{\cdot}6$ tons.

$18{\cdot}35a + 3{\cdot}36 = 61{\cdot}6$

Ability in end shear = a = 3·17 tons per ft.

Being weakest in longitudinal shear, this value (2·50 tons per foot) would be plotted in the Ability Graph.

On completion of the calculations of the abilities of all the different types of plate girder Spans on the Railway the results are entered up on charts for Bending Moment and Shear on tracing cloth. These charts show the effective length of Span, type of girder and the abilties of each type. Specimen Charts are shown in Plates V and VI.

When all these calculations are completed, we possess accurate knowledge of the uniformly distributed load which each Span will carry without overstressing any part of the Span, and we know to what extent each Span would be loaded by any engine, in terms of an uniformly distributed load.

All that remains is to arrange the information in such a manner that comparison between the strength of any girder and the E.U.D.L. of any engine can easily and quickly be made.

This is effected by preparing graphs of the abilities for Shear and Bending Moment separately of each section of the Railway. In these "Abilities of Section" graphs, the length of

Span is plotted horizontally, and the abilities of the weakest girder of each different length of Span on the section are plotted vertically. If, for instance, there were ten 20 foot Spans on a section, all of which were the same strength except one, which was not so strong as the other nine, the ability of the solitary weak span would be plotted. An "Ability of Section" graph for Shear and B.M. is show in Plates VII (a), VII (b), VIII (a) and VIII (b).

If now it is desired to know whether a particular engine may run over a certain section, all that is necessary is to place the E.U.D.L. Chart of the engine in question over the Ability Chart of the Section. If the Ability line does not fall below the E.U.D.L. line, in either the Shear or Bending Moment Charts, then the engine may run at unrestricted speed on the section, and no girders will suffer overstress thereby.

Supposing, however, that it is found that the Shear Ability line falls below the E.U.D.L. line at 66·25 feet span. The Ability Chart tells us the type Number of the Span whose ability at 66·25 feet span is below the E.U.D.L. of the engine, and, in order to ascertain which particular member of the Span is weak, the Ability Chart of the Span itself is placed over the E.U.D.L. Chart of the engine. It will at once be seen that the weakness lies in say Diagonal No. 4.

If the particular engine in question is run at speed over the bridge, diagonal No. 4 will be overstressed, and the extent of the overstress can very easily be ascertained by a reference to the calculation books of the girder.

Supposing that the member in question were diagonal No. 4 of B.N.R. girder type No. 8026. The calculation of the ability of this member is given on pages 544 and 545 from which it will be seen that—

$$2{\cdot}76 + (31{\cdot}58 \times \text{the ability}) = \text{Cross sectional area} \times \text{Stress}.$$

For the purpose of this illustration, let us suppose that the E.U.D.L. for Shear of the Engine on a loaded length of 66·25 feet is 3·80 tons. This, of course, is also the minimum permissible value for the ability of the member, if it is not to be overstressed. This value can therefore be placed as the ability in the above equation. The Cross sectional area can be obtained from the Chart of properties on page 542. The equation thus becomes :—

$$2{\cdot}76 + (31{\cdot}58 \times 3{\cdot}80) = 11{\cdot}60 \times f,$$

from which $f = 10{\cdot}60$ tons per square inch.

Conversely, the cross sectional area of the material which must be added to the member to avoid overstress can be ascertained.

But Transportation Officers appear to be chosen for their pertinacity. They are rarely, if ever, content with an assurance that they must not run an engine over a certain bridge at unrestricted speed. They almost most invariably ask "Well, if we cannot run it at unrestricted speed, at what speed *may* we run it" and, as always, they want an immediate reply.

In the case of Plate Spans (which includes rail bearers and cross girders) the system given in this paper enables the Bridge Engineer to give a fairly quick, if not exactly an immediate reply.

For existing bridges, the Bridge Rules lay down that the Impact factor may be worked out by the formula :—

$$I = \frac{V}{60} \times \frac{65}{45 + L}$$

Where V = Speed in Miles per hour, and L = Loaded length of span in feet. But the Impact factor employed in all our ability calculations is derived from the formula :—

$$I = \frac{65}{45 + L}$$

or in other words our Ability Charts show the loads which the bridges will carry when that load is travelling at sixty five miles per hour, that is to say, at what is known as "Unrestricted Speed."

But if, in the case of a girder which is weak for unrestricted speed, we assume that its ability is equal to the E.U.D.L. of the engine we wish to run, and employ the former of the two formulae above as the Impact factor, we arrive at a value for V, which is the maximum speed at which the engine in question may cross the bridge.

Take the case of the 40 foot clear span whose ability for Bending Moment is given on pages 550 to 551.

In this case Impact plus Unity (=i) for unrestricted speed is 1·747, and the B.M. ability of the girder is :—

$$\frac{1{\cdot}73 - 0{\cdot}16}{1 + I} \times 2 = 1{\cdot}79 \text{ tons per foot run.}$$

But supposing the E.U.D.L. for Bending of the engine under consideration was 2·16 tons per foot on a 42 foot span. The engine can only run on the span if the ability of the latter is not less than 2·16 tons per foot.

$$\text{Then } \frac{1{\cdot}73 - 0{\cdot}16}{1 + I} \times 2 = 2{\cdot}16$$

from which we get $I = 0{\cdot}42$

$$\text{But } I = \frac{V}{60} \times \frac{65}{45 + L}$$

$$\text{Or } 0{\cdot}42 = \frac{V}{60} + \frac{65}{45 + 42}$$

from which we get $V = 34$ miles per hour.

Comparison of the E.U.D.L. with the ability charts is greatly facilitated by means of a "Viewing box", consisting of a wooden box with a glass lid, the size of the lid being slightly larger than the charts, and the box containing two electric lights. A sketch of a Viewing box is given in Plate No. IX.

This completes the evolution of the system so far as it has progressed on the Bengal Nagpur Railway. The calculations necessary for the preparation of the charts have involved a great deal of work, but it has all been done by the regular Drawing Office staff. While the staff are to be congratulated on their effort, the writer is of the opinion that it was a mistake. Had the work been done by Computors engaged specially for the purpose, the degree of uniformity and continuity would have been greater than has actually been attained, and, of course, it would have been completed much earlier. How long it has taken to complete is difficult to say. It was started, probably about four years ago, by the writer's predecessor, Mr. R. Striek, and for a long time work was done on it only when other work was not pressing.

As investigation progresses, and further possibilities become apparent, one is led to doubt if all the implications of the scheme were fully realized when it was started. One, I am sure was not anticipated, and that is that the introduction of the scheme has forced the Railway to reduce speeds on many bridges. But in this case one can surely apply only half the adage—our ignorance was possibly blissful, but it cannot be said that it has been a folly to make ourselves wise.

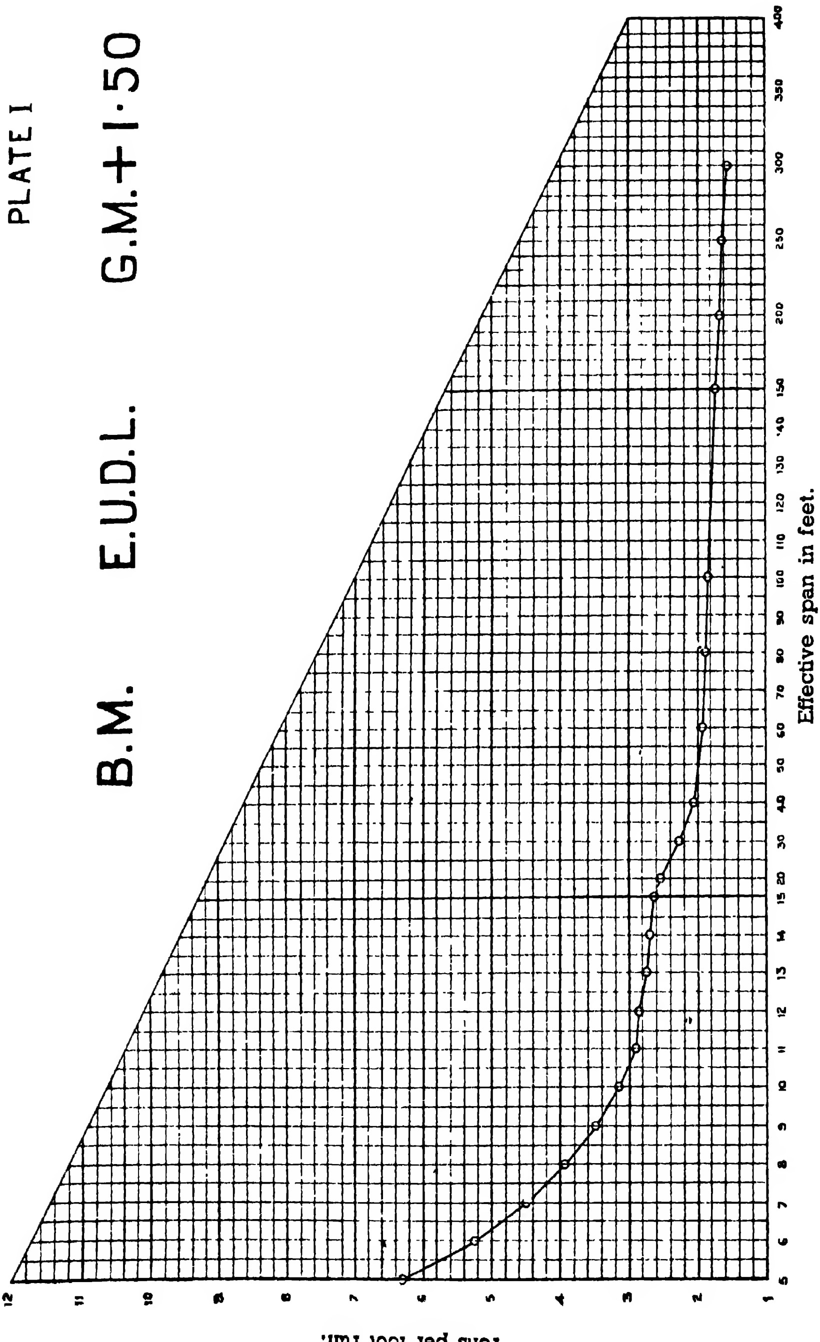


PLATE I
B.M. E.U.D.L. G.M.+1·50
Effective span in feet.
Tons per foot run.
5 6 7 8 9 10 11 12 13 14 15 20 30 40 50 60 70 80 90 100 110 120 130 140 150 200 250 300 350 400
1 2 3 4 5 6 7 8 9 10 11 12

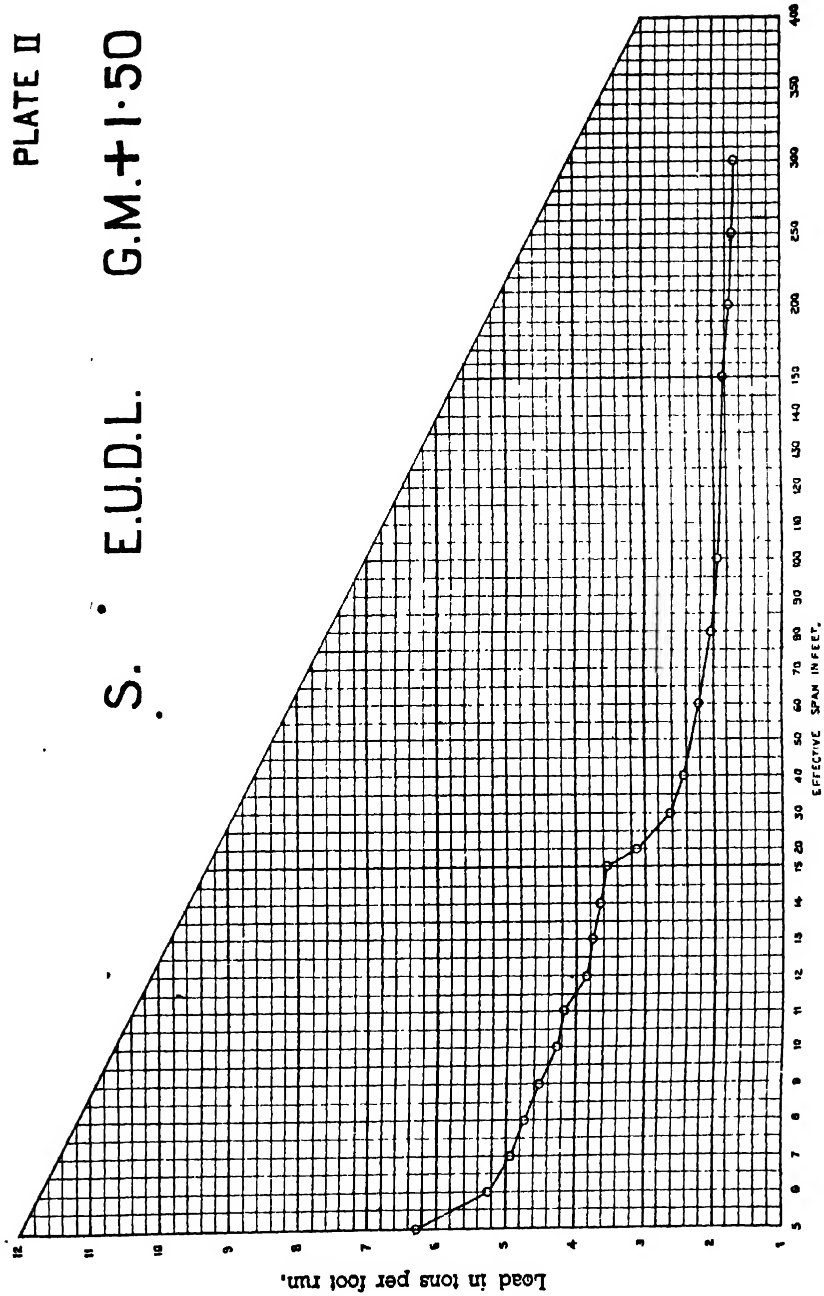


PLATE II
S. E.U.D.L. G.M.+1·50
EFFECTIVE SPAN IN FEET.
Load in tons per foot run.

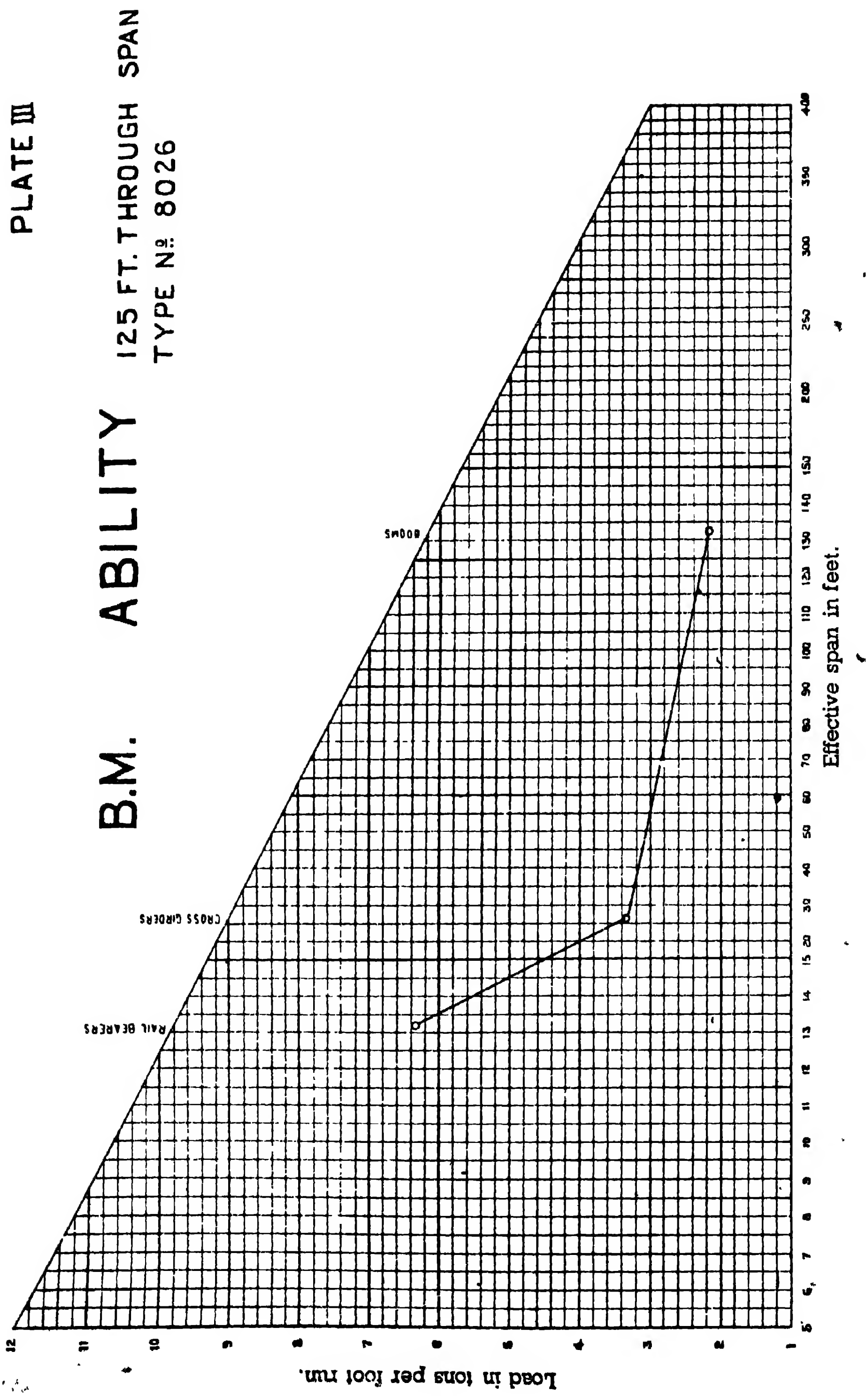
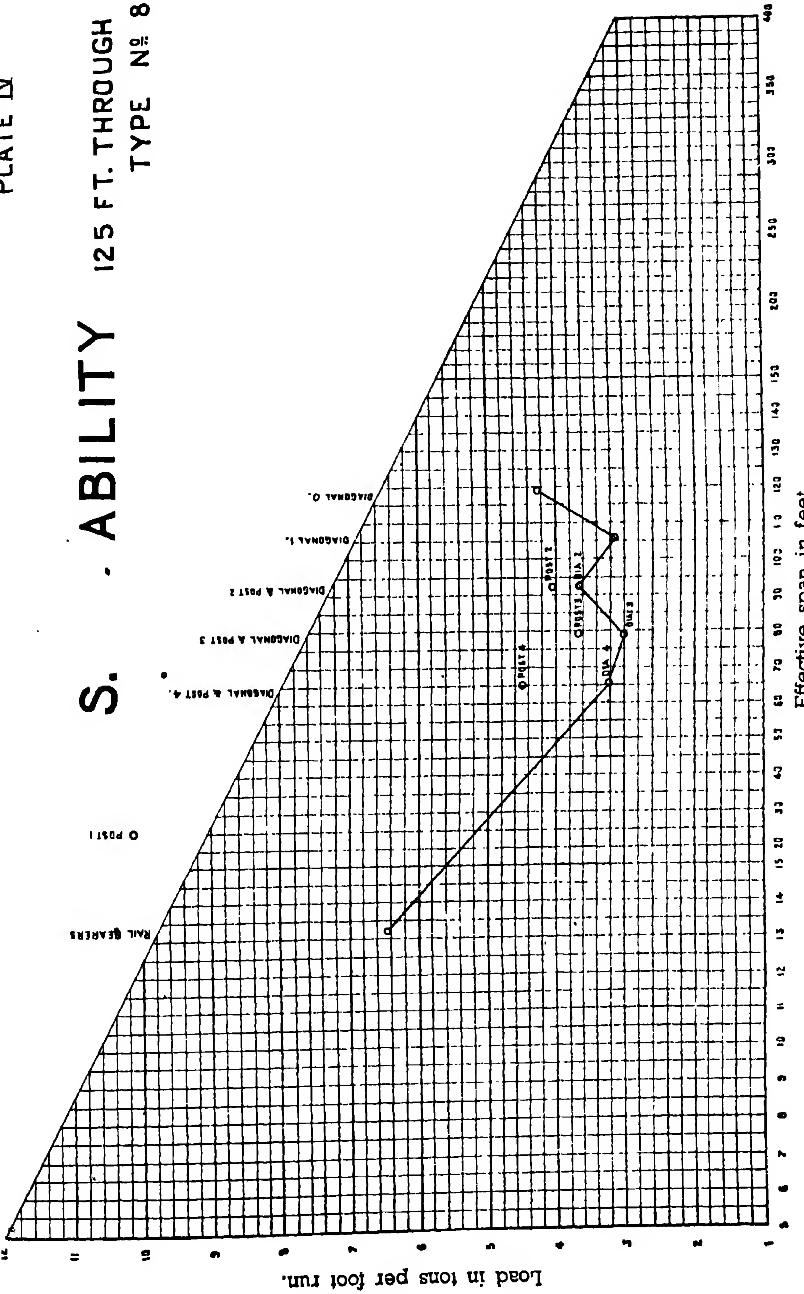


PLATE III
B.M. ABILITY
125 FT. THROUGH SPAN
TYPE No. 8026
BOOMS
CROSS GIRDERS
RAIL BEARERS
Effective span in feet.
Load in tons per foot run.

PLATE IV

S. ABILITY 125 FT. THROUGH SPAN TYPE No. 8026.



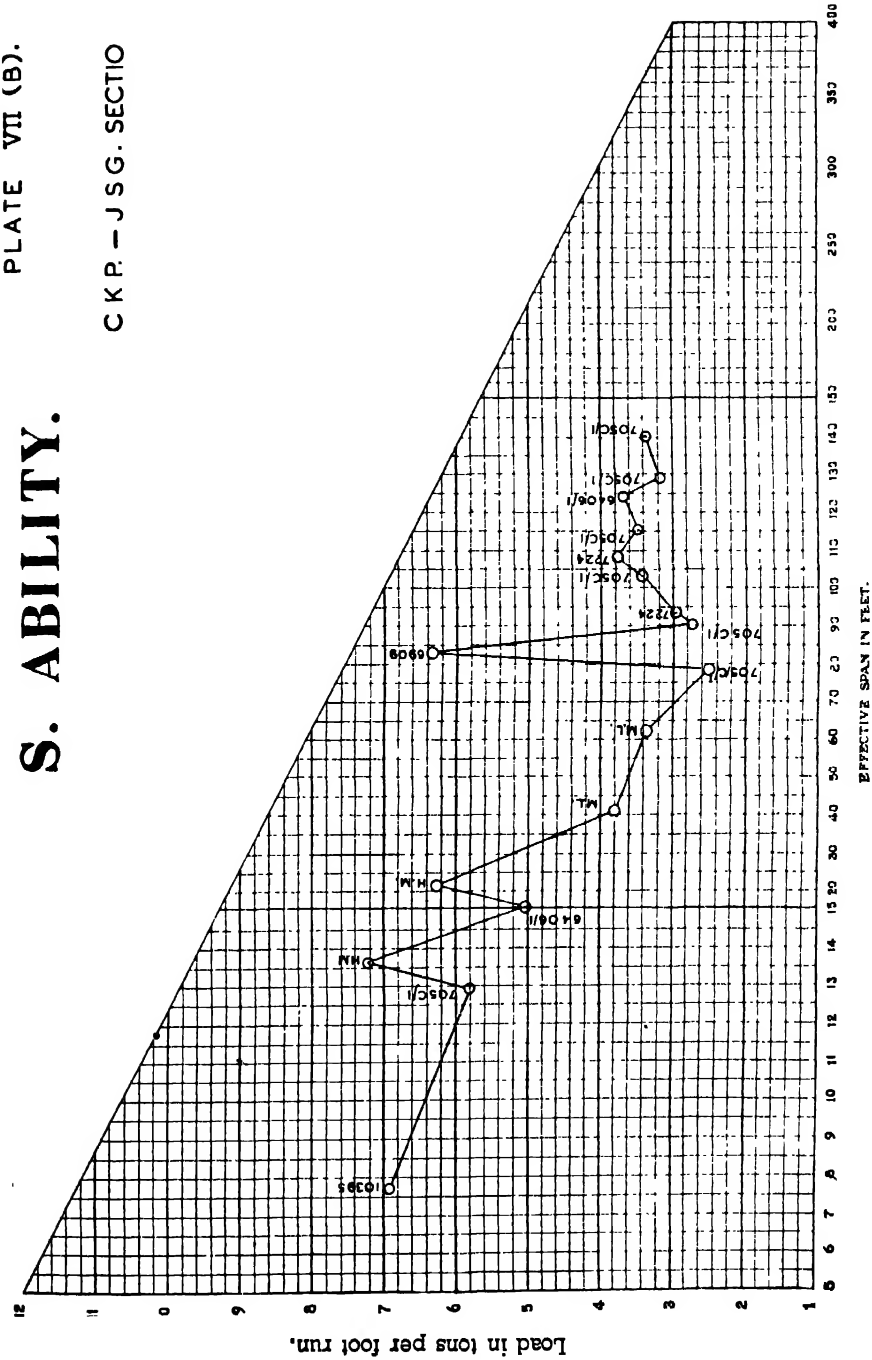
CHAKARDHARPUR—JHARSUGUDA *Plate VIII (b)*

SPAN	TYPE	NUMBER	ABILITIES B M	REMARKS
6′—0″	10395	3	6 25	
12′—0″	489E	5	5 60	
,,	10396	11	H M.	
20′—0″	10397	18	H M.	
,,	7241	4	4·20	
40′—0″	400A	12	M L	
,,	362A/1	4	4 7	
,,	10270/1	15	H.M	
,,	10266	6	H M	
60′—0″	10291	11	H M	
,,	701/C	4	M L	
80′—0″	6903	9	3·94	
150′—0″	6406/1	1	4 83	FOR R B LOADED LENGTH = 15·5
			3 00	FOR "X" GIRDER ,, ,, 31 0
			3·28	,, BOOMS ,, ,, 155 0
,,	705C/1	3	5 15	FOR R.B. LOADED LENGTH = 12 92
			4·05	,, "X" GIRDER ,, ,, 25·84
			2 92	,, BOOMS ,, ,, 155 0
,,	7224	9	5 98	FOR R.B. LOADED LENGTH = 15·5
			2·14	,, "X" GIRDER ,, ,, 31·0
			2·82	,, BOOMS ,, ,, 155·0

PLATE VII (B).

S. ABILITY.

CKP.—JSG. SECTIO



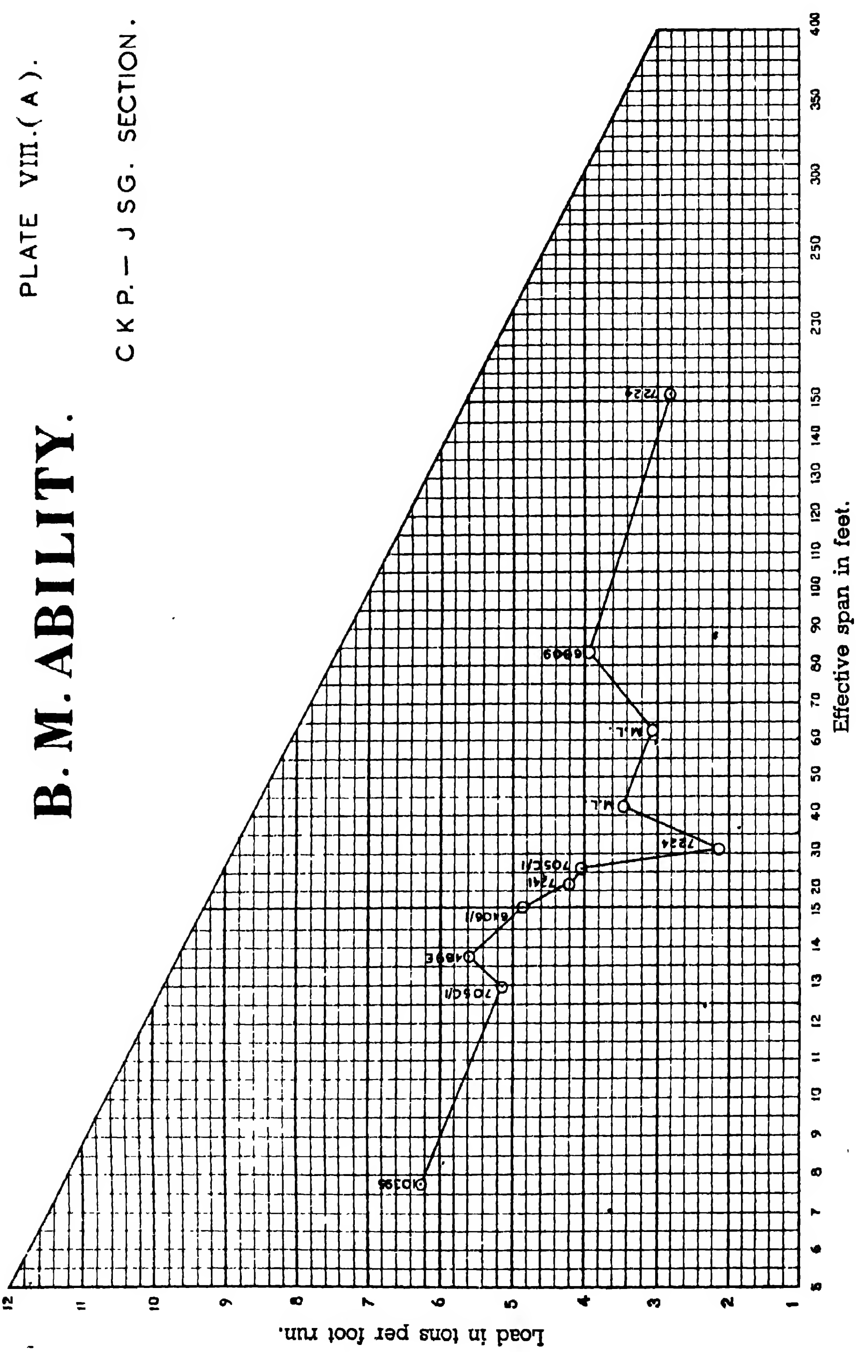


PLATE VIII.(A).
B. M. ABILITY.
C K P. — J S G. SECTION.
Effective span in feet.
Load in tons per foot run.

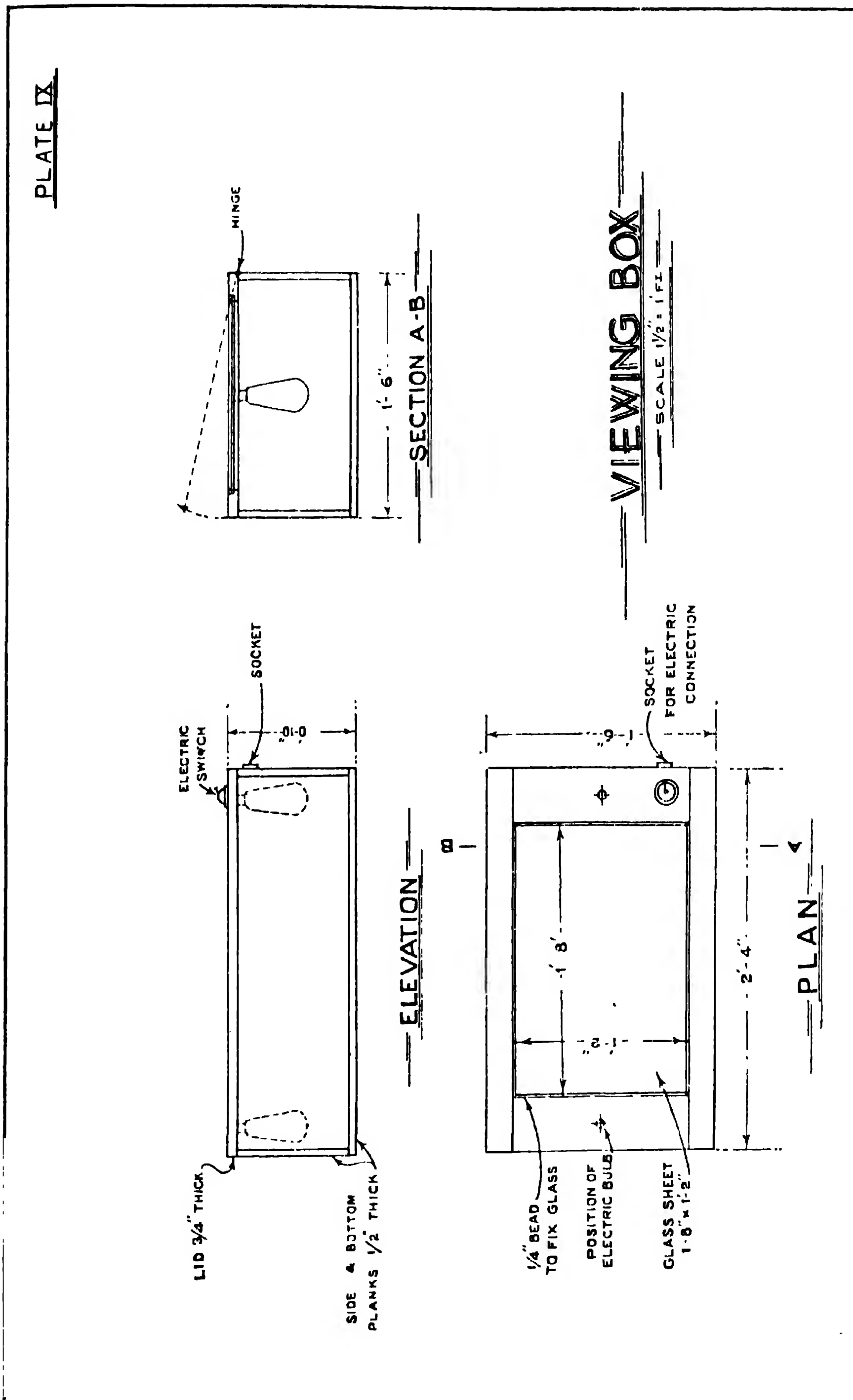


PLATE IX
HINGE
SECTION A-B
1'-6"
VIEWING BOX
SCALE 1½" = 1 FT
ELECTRIC SWITCH
SOCKET
0-10"
ELEVATION
LID 3/4" THICK
SIDE & BOTTOM PLANKS 1/2" THICK
SOCKET FOR ELECTRIC CONNECTION
1'-6"
B
A
PLAN
1'-8"
1'-2"
2'-4"
1/4" BEAD TO FIX GLASS
POSITION OF ELECTRIC BULB
GLASS SHEET 1'-8" x 1'-2"

APPENDIX I

THROUGH SPANS

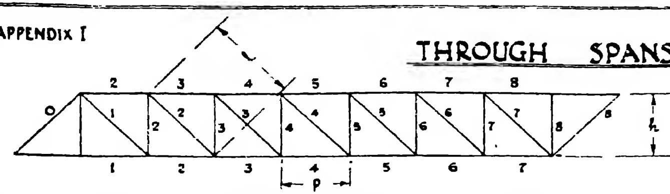


TABLE OF CONSTANTS FOR USE IN CALCULATING ABILITIES OF MAIN GIRDERS OF TRIANGULATED SPANS.

—NOTE—

M – Number of bays in span.
D – Dead load per span.
l – Length of diagonal.
p – Panel length.
h – Length of girder between intersections.
a – Ability.
I – Impact & unity.

DEAD LOAD CONSTANTS / LIVE LOAD CONSTANTS.

		0	1	2	3	4	5	6	7	8	DEAD	LIVE	0	1	2	3	4	5	6	7	8
M·16	POSTS		-4	35	29	23	17	11	5	2	D/192	$\frac{a.I.p.}{64}$		-32	182	156	132	110	90	72	0
	DIAGONALS	45	-39	-33	-27	-21	-15	-9	-3		" × l/h	$\frac{a.I.p.}{64}\,l/h$	240	2 -210	6 -182	12 -156	20 -132	30 -110	42 -90	56 -72	
	BOOMS		45	84	117	144	165	180	189	192	" × p/h	$\frac{a.I.p.}{4}\,p/h$		15	28	39	48	55	60	63	64
M·14	P.		-4	29	23	17	11	5	2		D/168	$\frac{a.I.p}{56}$		-28	132	110	90	72	56	0	
	D.	39	-33	-27	-21	-15	-9	-3			" × l/h	$\frac{a.I.p}{56}\,l/h$	182	2 -156	6 -132	12 -110	20 -90	30 -72	42 -56		
	B.		39	72	99	120	135	144	147		" × p/h	$\frac{a.I.p.}{4}\,p/h$		13	24	33	40	45	48	49	
M·12	P.		-4	23	17	11	5	2			D/144	$\frac{a.I.p}{48}$		-24	90	72	56	42	0		
	D.	33	-27	-21	-15	-9	-3				" × l/h	$\frac{a.I.p.}{48}\,l/h$	132	2 -110	6 -90	12 -72	20 -56	30 -42			
	B.		33	60	81	96	105	108			" × p/h	$\frac{a.I.p.}{4}\,p/h$		11	20	27	32	35	36		
M·10	P.		-4	17	11	5	2				D/120	$\frac{a.I.p}{40}$		-20	56	42	30	0			
	D.	27	-21	-15	-9	-3					" × l/h	$\frac{a.I.p}{40}\,l/h$	90	2 -72	6 -56	12 -42	20 -30				
	B.		27	48	63	72	75				" × p/h	$\frac{a.I.p.}{4}\,p/h$		9	16	21	24	25			
M·8	P.		-4	11	5	2					D/96	$\frac{a.I.p.}{32}$		-16	30	20	0				
	D.	21	-15	-9	-3						" × l/h	$\frac{a.I.p}{32}\,l/h$	56	2 -42	6 -30	12 -20					
	B.		21	36	45	48					" × p/h	$\frac{a.I.p}{4}\,p/h$		7	12	15	16				

APPENDIX I

—DECK SPANS—

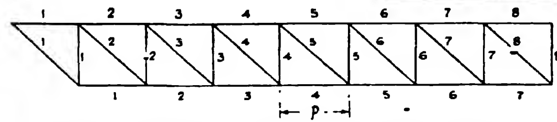


TABLE OF CONSTANTS FOR USE IN CALCULATING ABILITIES OF MAIN GIRDERS OF TRIANGULATED SPANS.

—NOTE—

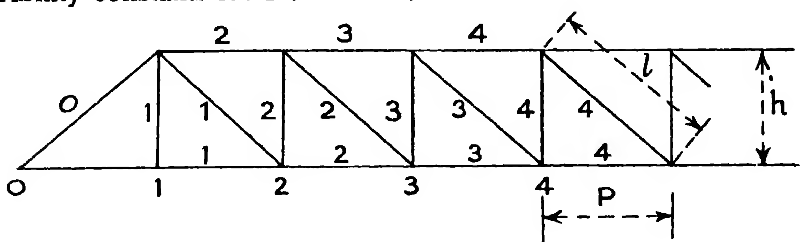
M – Number of bays in span.
D – Dead load per span.
l – Length of diagonal.
p – Panel length.
h – Length of girder between intersections.
a – Ability
I – Impact & unity.

DEAD LOAD CONSTANTS. LIVE LOAD CONSTANTS.

		Dead 0	Dead 1	Dead 2	Dead 3	Dead 4	Dead 5	Dead 6	Dead 7	Dead 8	DEAD	LIVE	Live 0	Live 1	Live 2	Live 3	Live 4	Live 5	Live 6	Live 7	Live 8
M·16	POSTS		43	37	31	25	19	13	7	4	$D/192$	$\frac{a.I.p}{64}$		240	210	182	156	132	110	90	32
	DIAGONALS		-45	-39	-33	-27	-21	-15	-9	-3	$- \times l/h$	$\frac{a.I.p}{64} l/h$		240	210	182	12 156	20 132	30 110	42 90	56 72
	BOOMS		45	84	117	144	165	180	189	192	$- \times p/h$	$\frac{a.I.p}{4} p/h$		15	28	39	48	55	60	63	64
M·14	P.		37	31	25	19	13	7	4		$D/168$	$\frac{a.I.p}{56}$		182	156	132	110	90	72	28	
	D.		-39	-33	-27	-21	-15	-9	-3		$- \times l/h$	$\frac{a.I.p}{56} l/h$		182	156	132	12 110	20 90	30 72	42 56	
	B.		39	72	99	120	135	144	147		$- \times p/h$	$\frac{a.I.p}{4} p/h$		13	24	33	40	45	48	49	
M·12	P.	.	31	25	19	13	7	4			$D/144$	$\frac{a.I.p}{48}$		132	110	90	72	56	24		
	D.		-33	-27	-21	-15	-9	-3			$- \times l/h$	$\frac{a.I.p}{48} l/h$		132	110	90	12 72	20 56	30 42		
	B.		33	60	81	96	105	108			$- \times p/h$	$\frac{a.I.p}{48} p/h$		11	20	27	32	35	36		
M·10	P.		25	19	13	7	4				$D/120$	$\frac{a.I.p}{40}$		90	72	56	42	20			
	D.		-27	-21	-15	-9	-3				$- \times l/h$	$\frac{a.I.p}{40} l/h$		90	72	6 56	12 42	20 30			
	B.		27	48	63	72	75				$- \times p/h$	$\frac{a.I.p}{4} p/h$		9	16	21	24	25			
M·8	P.		19	13	7	4					$D/96$	$\frac{a.I.p}{32}$		56	42	30	16				
	D.		-21	-15	-9	-3					$- \times l/h$	$\frac{a.I.p}{32} l/h$		56	42	6 30	12 20				
	B.		21	36	45	48					$- \times p/h$	$\frac{a.I.p}{4} p/h$		7	12	15	16				

Through Span.

Ability constants for Dead Load.



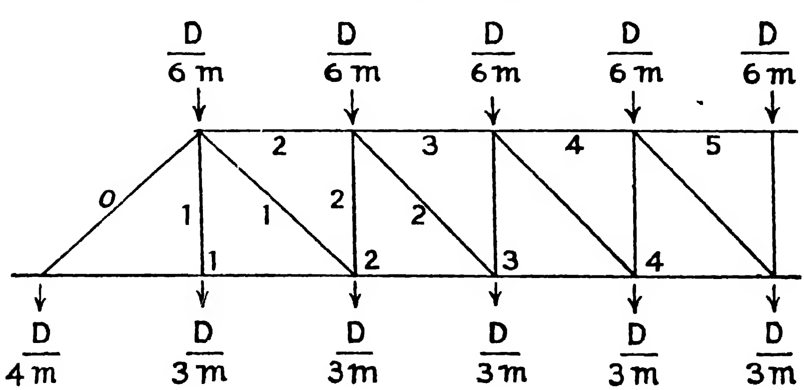
Panel length	=	p
Height between intersections	=	h
Length of diagonal	=	l
Number of panels	=	m
Dead Load per span	=	D Tons.
Dead Load per girder	=	$\frac{D}{2}$,,
Dead Load per panel	=	$\frac{D}{2m}$,,

$\frac{2}{3}$rd of Dead Load per panel, is assumed concentrated at bottom panel points and $\frac{1}{3}$rd at top panel points. The end panel points each carry half panel Load.

Bottom panel point loads $= \frac{2}{3} \times \frac{D}{2m} = \frac{D}{3m}.$

Top panel point loads $= \frac{1}{3} \times \frac{D}{2m} = \frac{D}{6m}.$

End panel point loads $= \frac{1}{2} \times \frac{D}{2m} = \frac{D}{4m}.$



End reaction $= \frac{1}{2} \times \frac{D}{2} = \frac{D}{4}$

Chord Members.

The force in any chord Member say n^{th} is

$$= \frac{\text{Bending Moment about } n^{th} \text{ panel point}}{\text{height (h)}}$$

Bending Moment about n^{th} panel point =

$$\left(\frac{D}{4} - \frac{D}{4m}\right) np - (n-1) \frac{D}{2m} \left[1 + \frac{(n-2)}{2} \right] p$$

$$= \left(\frac{D}{4} - \frac{D}{4m}\right) np - \frac{D}{2m} P. (n-1) \frac{n}{2}$$

$$= \frac{DP}{4} n \left\{ 1 - \frac{1}{m} - \frac{(n-1)}{m} \right\}$$

$$= \frac{DP}{4m} n (m-n)$$

$$\text{Force in chord} = \frac{DP}{4m} n \frac{(m-n)}{h}$$

$$= \frac{DP}{h} n \frac{(m-n)}{4m}$$

$$= \frac{DP}{h} 3n \frac{(m-n)}{12\,m}$$

Taking a span with say 10 panels

$$\text{Force in } n^{th} \text{ chord} = \left[\frac{DP}{h} \times \frac{1}{120} \right] 3n\,(10-n)$$

Force in chord 1 = $\frac{DP.}{h} \times \frac{1}{120} \times 27$

2 = ,, × 48

3 = ,, × 63

4 = ,, × 72

5 = ,, × 75

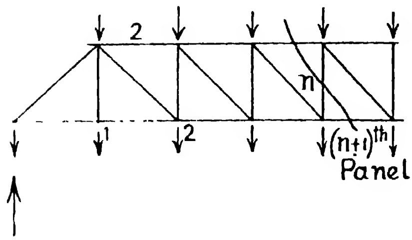
From symmetry force in chord 6 will be same as in 5 and the constants need not be worked further.

Posts.

Force in any vertical say n^{th} vertical

= Shear in $(n+1)^{th}$ panel as shown in the sketch.

$$\text{Shear in } (n+1)^{th} \text{ panel} = \left(\frac{D}{4} - \frac{D}{4m}\right) - (n-1) \times \frac{D}{2m} - \frac{D}{3m}$$



$$= \frac{D}{12m}\left\{3m - 3 - 6n + 6 - 4\right\}$$

$$= \frac{D}{12m}(3m - 6n - 1)$$

But Force in the 1st post and central post will be equal to the panel loads respectively.

Taking a span with 10 panels

Force in 1st post $= \frac{D}{3m} = \frac{D}{30} = \frac{D}{120} \times 4$ (Tension)

,, 2nd ,, $= \frac{D}{120} \times (30 - 6 \times 2 - 1) = \frac{D}{120} \times 17$ (Compn)

,, 3rd ,, $= \frac{D}{120} \times (30 - 6 \times 3 - 1) = \frac{D}{120} \times 11$,,

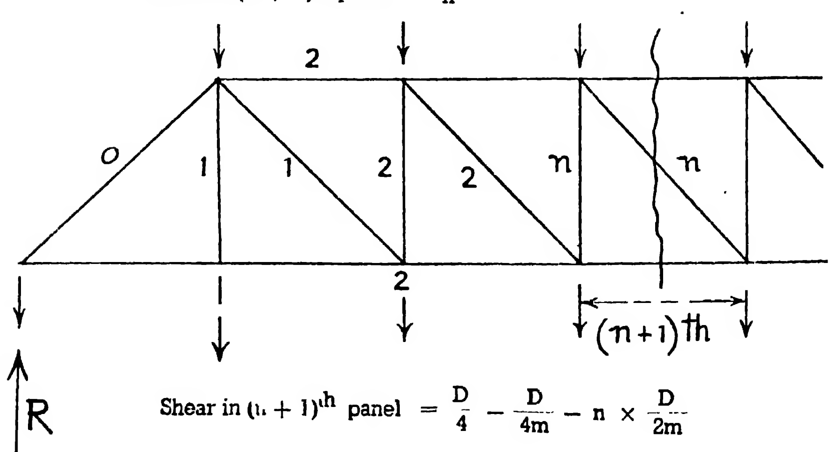
,, 4th ,, $= \frac{D}{120} \times (30 - 6 \times 4 - 1) = \frac{D}{120} \times 5$,,

,, 5th ,, $= \frac{D}{6m} = \frac{D}{60} = \frac{D}{120} \times 2$ (Compn)

Diagonals.

Force in any diagonal say n^{th}

$= \text{Shear in } (n + 1)^{th} \text{ panel} \times \frac{1}{h}$



Shear in $(n + 1)^{th}$ panel $= \frac{D}{4} - \frac{D}{4m} - n \times \frac{D}{2m}$

$$= \frac{D}{4m}(m - 1 - 2n)$$

Force in n^{th} diagonal $= \frac{D}{4m}(m - 2n - 1) \times \frac{1}{h}$

Taking again the span with 10 panels

$$\text{Force in } n^{th} \text{ diagonal} = \frac{D}{40} \times \frac{1}{h} \times (10 - 2n - 1)$$

$$= \frac{D}{120} \times \frac{1}{h} \quad (30 - 6n - 3)$$

$$\text{Force in End diagonal } (n = 0) = \frac{D}{120} \times \frac{1}{h} (30 - 6 \times 0 - 3) = \frac{D}{120}\frac{1}{h} \times 27$$

$$\text{Force in 1st diagonal} = \frac{D}{120} \times \frac{1}{h} (30 - 6 \times 1 - 3) = \frac{D}{120}\frac{1}{h} \times 21$$

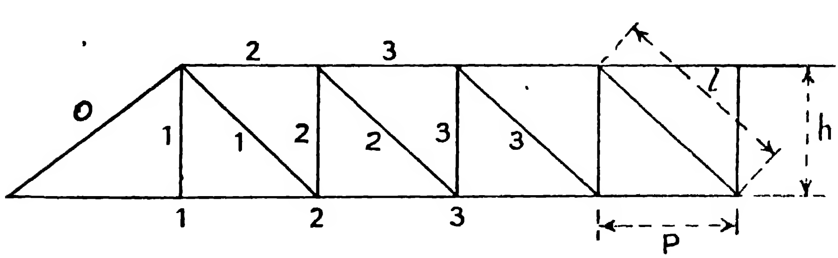
,,	2nd ,,	=	,,	$(30 - 6 \times 2 - 3) =$	,,	$\times$ 15
,,	3rd ,,	=	,,	$(30 - 6 \times 3 - 3) =$	,,	$\times$ 9
,,	4th ,,	=	,,	$(30 - 6 \times 4 - 3) =$	,,	$\times$ 3

The constants for any other span, with different number of panels can be derived in a similar way.

Through Span.

Ability constants for Live Load.

(Conventional method.)



Panel length	=	P	Number of panels	=	m
Height between intersections	=	h	Live load	=	a Tons/ft/span.
Length of Diagonal	=	l	Impact factor + Unity	=	I

Chord Members.

$$\text{Force in any chord Member} = \frac{\text{Bending Moment about corresponding panel point}}{\text{height h.}}$$

Bending Moment about any panel point is maximum when the whole span is loaded.

Live load including impact per panel per girder $= \dfrac{a. I. P}{2}$

End panel load $= \frac{1}{2}. \dfrac{a. I. P}{2} = \frac{1}{4}\ a. I. P$

End Reaction $= \frac{1}{2}. \dfrac{m. a. I. P}{2} = \dfrac{m. a. I. P}{4}$

Bending Moment about n^{th} panel point

$$= \frac{m. a. I. P.}{4} nP - \frac{a. I. P.}{4} np - (n-1) \frac{a. I. P.}{2} \left(1 + \frac{n-2}{2}\right) P$$

$$= \frac{m. a. I. P}{4} np - \frac{a. I. P}{4} nP - \frac{(n-1)(a. I. P)}{4} nP$$

$$\frac{a. I. P.}{4} nP \left\{ m-1-n+1 \right\}$$

$$\frac{a. I. P}{4} np \left\{ m-n \right\}$$

Force in n^{th} chord $= \dfrac{a. I. P.}{4}\ \dfrac{P}{h}\ n\ (m-n)$

Taking a span with 10 panels

Force in n^{th} chord $= \dfrac{a. I. P.}{4}\ \dfrac{P}{h}\ n\ (10-n)$

Force in 1st chord	=	$\frac{a. I. P.}{4}$	$\times \frac{P.}{h}$	$\times 1 \times 9 =$	$\frac{a. I. P.}{4}$	$\times \frac{P.}{h}$	$\times 9$
,, 2nd ,,	=	,,		$\times 2 \times 8 =$	,,		$\times 16$
,, 3rd ,,	=	,,		$\times 3 \times 7 =$	,,		$\times 21$
,, 4th ,,	=	,,		$\times 4 \times 6 =$	,,		$\times 24$
,, 5th ,,	=	,,		$\times 5 \times 5 =$	,,		$\times 25$

From symmetry force in the 6^{th} chord will be same as in the 5^{th} chord and so on and the constants need not be worked further.

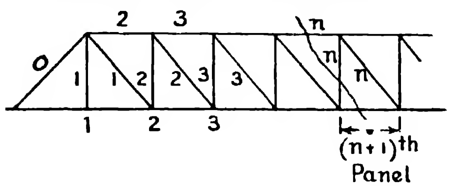
Web Members.

The force in Web Members is maximum when the shear force in corresponding panel is maximum. Maximum positive shear in any panel occurs when all panel points to the right of panel are fully loaded, and maximum

negative shear occurs when all panel points to the left of panel are fully loaded. It is seen that this assumption is not quite true, since it is not possible to fully load any panel points, without simultaneously loading the panel points adjacent to it. However it is on the safe side and the percentage error involved is small.

Posts.

Force in n^{th} post $=$ Shear in $(n + 1)^{th}$ panel.



For maximum positive shear in $(n + 1)^{th}$ panel, number of panel points to be fully loaded on the right $= (m - n - 1)$.

Effective load on the girder $= \frac{a.\ I.\ P.}{2} (m-n-1)$

Distance of centre of gravity of this load from

$$\text{Right Hand Support} = \left\{ 1 + \frac{(m-n-2)}{2} \right\} P$$

$$= \frac{(m-n)}{2} P$$

$$\text{Left Hand reaction} = \frac{a.\ I.\ P.}{2} (m-n-1) \frac{(m-n)}{2} P \quad \frac{1}{mP}$$

$$\text{Positive shear in } (n+1)^{th} \text{ panel} = \frac{a.\ I.\ P.}{4m} (m-n-1)\ (m-n)$$

For maximum negative shear, all the panel points to the left are fully loaded.

Number of panel points to be fully loaded $= n$

$$\text{Effective load on girder} = \frac{n.\ a.\ I.\ P}{2}$$

Distance of centre of gravity of this load from the

$$\text{Left Hand support} = \left\{ 1 + \frac{n-1}{2} \right\} P = \frac{n+1}{2} P$$

$$\text{Right Hand Reaction} = \frac{a.\ I.\ p.}{2} n \frac{(n+1)}{2} \frac{P}{m.\ P}$$

$$\text{Maximum negative shear in panel} = \frac{a.\ I.\ P.}{4m} n\ (n+1)$$

$$\text{Maximum positive force in } n^{th} \text{ post} = \frac{a.\ I.\ P.}{4m} (m-n-1)\ (m-n)$$

$$\text{Maximum negative force in } n^{th} \text{ post} = \frac{a.\ I.\ P.}{4m} n\ (n+1)$$

Force in the 1st post is maximum when the panel point load is maximum and is equal to $\frac{a. I. P.}{2}$ and there is no negative force in this Member.

Taking a span of 10 panels

Positive force in n^{th} post $= \frac{a. I. P.}{40} (10 - n)\ (9 - n)$

Negative force in n^{th} post $= \frac{a. I. P.}{40}\ n\ (n + 1)$

Post.	Positive force.		Negative force.	
1	$\frac{a. I. P.}{2}$	$= \frac{a. I. P}{40} \times 20$	$\frac{a. I. P.}{40}\ 1 \times 2$	$= \frac{a. I. P.}{40} \times 2$
2	$\frac{a. I. P.}{40} \times 8 \times 7$	$= \frac{a. I. P.}{40} \times 56$	$\frac{a. I. P.}{40}\ 2 \times 3$	$= \frac{a. I. P.}{40} \times 6$
3	,, $\times 7 \times 6$	= ,, $\times 42$	,, 3×4	= ,, $\times 12$
4	,, $\times 6 \times 5$	= ,, $\times 30$	,, 4×5	= ,, $\times 20$
5	$\times 0$	since there is no live load in this post.		

Force in any diagonal $=$ Shear in corresponding panel $\times \frac{1}{h}$

Force in n^{th} diagonal $=$ Shear in $(n + 1)^{th}$ panel $\times \frac{1}{h}$

Positive force in n^{th} diagonal $= \frac{a. I. P.}{4m}\ \frac{1}{h}\ (m - n - 1)\ (m - n)$

Negative force in n^{th} diagonal $= \frac{a. I. P.}{4m}\ \frac{1}{h}\ n\ (n + 1)$

Taking again the span with 10 panels.

Positive force in n^{th} diagonal $= \frac{a. I. P.}{40}\ \frac{1}{h}\ (10 - n)\ (9 - n)$

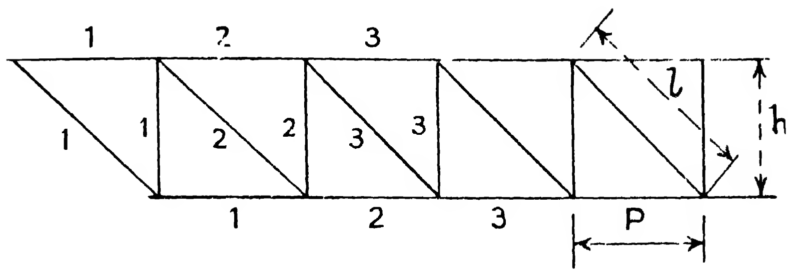
Negative force in n^{th} diagonal $= \frac{a. I. P.}{40}\ \frac{1}{h}\ n\ (n + 1)$

Diagonal.	Positive force.	Negative force.
0	$\frac{a. I. P.}{40}\ \frac{1}{h} \times 90$	0
1	,, $\times 72$	$\frac{a. I. P.}{40}\ \frac{1}{h} \times 2$
2	,, $\times 56$	,, $\times 6$
3	,, $\times 42$	,, $\times 12$
4	,, $\times 30$	,, $\times 20$

The constants for any other span with different number of panels can be worked out in a similar way.

DECK SPAN.

Ability Constants for Dead Load.



Panel length $= P$

Height between intersections $= h$

Length of diagonal $= l$

Number of panels $= M$

Dead load per span $= D$

Dead load per girder $= \frac{D}{2}$

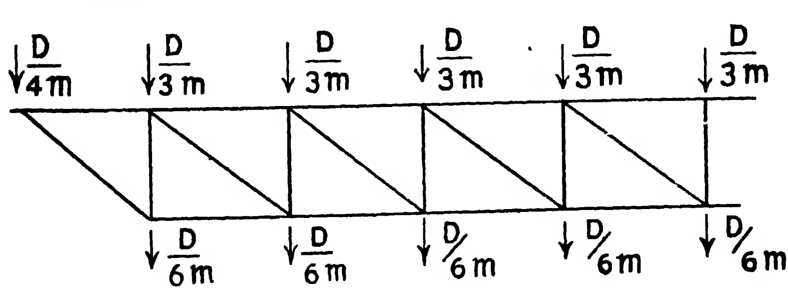
Dead load per panel 2m

$\frac{2}{3}$rd of dead load per panel is assumed concentrated at top panel points and $\frac{1}{3}$ rd at bottom panel points. The end panel points each carry half panel load.

Top panel points Loads $= \frac{2}{3} \times \frac{D}{2m} = \frac{D}{3m}$

Bottom panel points Loads $= \frac{1}{3} \times \frac{D}{2m} = \frac{D}{6m}$

End panel point Loads $= \frac{1}{2} \times \frac{D}{2m} = \frac{D}{4m}$



End reaction $= \frac{1}{2} \times \frac{D}{2} = \frac{D}{4}$

Chord Members.

The force in any chord member =

$$\frac{\text{Bending Moment about corresponding panel point}}{\text{height } h}$$

Bending Moment about n^{th} panel point =

$$\left(\frac{D}{4} - \frac{D}{4m}\right)nP - (n-1)\frac{D}{2m}\left[1 + \frac{n-2}{2}\right]P$$

$$= \left(\frac{D}{4} - \frac{D}{4m}\right)nP - \frac{D}{4m}n(n-1)P$$

$$= \frac{D}{4m}Pn(m-1-n+1)$$

$$= \frac{D}{4m}Pn(m-n)$$

Force in n^{th} chord $= \frac{D}{4m}\ \frac{P}{h}\ n(m-n)$

$= \frac{D}{12m}\ \frac{P}{h}\ 3n(m-n)$

Taking a span with 10 panels

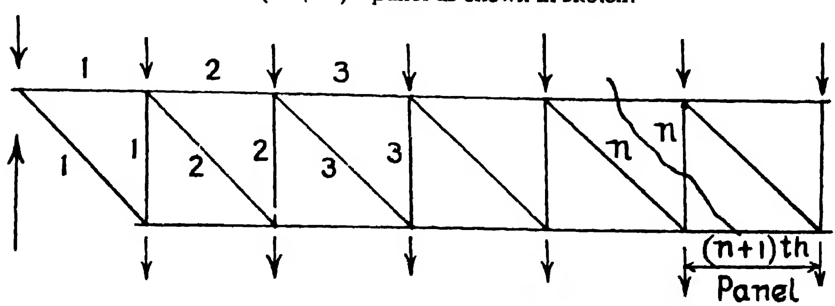
Force in n^{th} chord $= \frac{D}{120}\ \frac{P}{h}\ 3n(10-n)$

Force in chord	1	=	$\frac{D}{120}\ \frac{P}{h}$	27
,,	2	=	,,	48
,,	3	=	,,	63
,,	4	=	,,	72
,,	5	=	,,	75

From symmetry, force in chord 6 will be same as in 5 and the constants need not be worked further.

Posts. Force in any vertical say n^{th}

= Shear in $(n+1)^{th}$ panel as shown in sketch.



Shear in $(n+1)^{th}$ panel $= \frac{D}{4} - \frac{D}{4m} - (n-1)\frac{D}{2m} - \frac{D}{6m}$

$$= \frac{D}{12m}\left\{3m - 3 - 6n + 6 - 2\right\}$$

Shear in $(n+1)^{th}$ panel $= \frac{D}{12m}\left\{3m - 6n + 1\right\}$

Force in n^{th} post $= \frac{D}{12m}\left\{3m - 6n + 1\right\}$

Taking again the span with 10 panels

Force in n^{th} post $= \frac{D}{120}\left\{30 - 6n + 1\right\}$

$$= \frac{D}{120}(31 - 6n)$$

Force in 1st post $= \frac{D}{120}(31 - 6) = \frac{D}{120} \times 25$

,, 2nd ,, $= \frac{D}{120}(31 - 12) = \frac{D}{120} \times 19$

,, 3rd ,, $= \frac{D}{120}(31 - 28) = \frac{D}{120} \times 13$

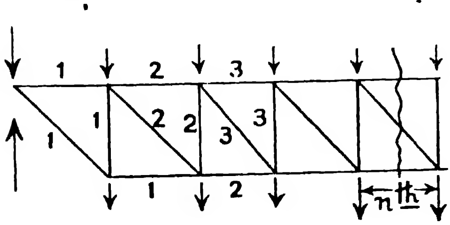
,, 4th ,, $= \frac{D}{120}(31 - 24) = \frac{D}{120} \times 7$

Force in the 5^{th} post = Top panel load $= \frac{D}{3 \times 10} = \frac{D}{120} \times 4$

Diagonals.

Force in any diagonal say n^{th} = Shear in n^{th} panel $\times \frac{1}{h}$

Shear in n^{th} panel $= \frac{D}{4} - \frac{D}{4m} - (n-1)\frac{D}{2m}$



$$= \frac{D}{12m}\left\{3m - 3 - 6n + 6\right\}$$

$$= \frac{D}{12m}(3m - 6n + 3)$$

Force in n^{th} diagonal $= \frac{D}{12m}\frac{1}{h}(3m - 6n + 3)$

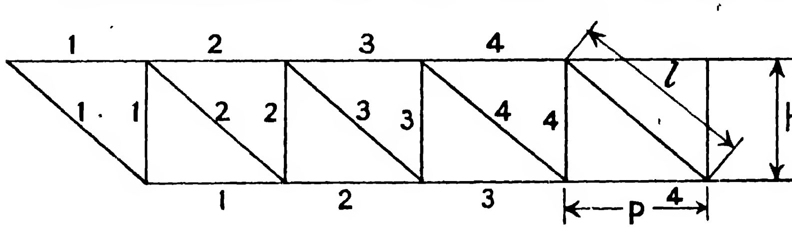
Taking the span with 10 panels

Force in n^{th} diagonal	=	$\frac{D}{120} \frac{1}{h} (33 - 6n)$
Force in 1st diagonal	=	$\frac{D}{120} \frac{1}{h} (33 - 6) = \frac{D}{120} \frac{1}{h} \times 27$
,, 2nd ,,	=	$\frac{D}{120} \frac{1}{h} (33-12) = \frac{D}{120} \frac{1}{h} \times 21$
,, 3rd ,,	=	$\frac{D}{120} \frac{1}{h} (33-18) = \frac{D}{120} \frac{1}{h} \times 15$
,, 4th ,,	=	$\frac{D}{120} \frac{1}{h} (33-24) = \frac{D}{120} \frac{1}{h} \times 9$
,, 5th ,,	=	$\frac{D}{120} \frac{1}{h} (33-30) = \frac{D}{120} \frac{1}{h} \times 3$

For any other span with different number of panels, the constants can be worked out in a similar way.

DECK SPAN.

Ability constants for Live Load. (Conventional method).



Panel length	= P
Height between intersections	= h
Length of Diagonal	= l
Number of panels	= m
Live load	= a tons/ft./span
Impact factor + Unity	= I.
Live load including impact per panel/girder	$= \frac{a.\ I.\ P.}{2}$

Chord Members.

$$\text{Force in any chord member} = \frac{\text{Bending Moment about corresponding panel point}}{\text{height h.}}$$

Bending Moment about any panel point is maximum when the whole span is loaded.

Panel load $= \dfrac{a.\,I.\,P.}{2}$

End panel load $= \tfrac{1}{2}.\,\dfrac{a.\,I.\,P.}{2} = \dfrac{a.\,I.\,P}{4}$.

End reaction $= \tfrac{1}{2}.\,\dfrac{m.\,a.\,I.\,P.}{2} = \dfrac{m.\,a.\,I.\,P.}{4}$

Bending moment about n^{th} panel point

$$= \frac{m.\,a.\,I.\,P.}{4}\,nP - \frac{a.\,I.\,P.}{4}\,nP - \frac{(n-1)}{2}\,a.\,I.\,P\left(1+\frac{n-2}{2}\right)P$$

$$= \frac{m.\,a.\,I.\,P}{4}\,nP - \frac{a.\,I.\,P}{4}\,nP - \frac{a.\,I.\,P.}{4}\,nP\,(n-1).$$

$$= \frac{a.\,I.\,P.}{4}\,nP\,(m-1-n+1)$$

$$= \frac{a.\,I.\,P.}{4}\,nP\,(m-n)$$

Force in n^{th} chord $= \dfrac{a\,I\,P.}{4}\;\dfrac{P}{h}\;n\,(m\text{-}n)$

Considering a span with 10 panels $(m-10)$

Force in n^{th} chord $= \dfrac{a.I\,P.}{4}\;\dfrac{P}{h} \times (10\text{-}n)$

Force in 1st chord $= \dfrac{a.I\,P}{4}\;\dfrac{P}{h} \times 9$

,, 2nd, ,, $= \dfrac{a\,I.P.}{4}\;\dfrac{P}{h} \times 16$

,, 3rd ,, $= \dfrac{a.I.P.}{4}\;\dfrac{P}{h} \times 21$

,, 4th ,, $= \dfrac{a.I.P.}{4}\;\dfrac{P}{h} \times 24$

,, 5th ,, $= \dfrac{a\,I\,P.}{4}\;\dfrac{P}{h} \times 25$

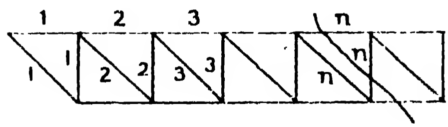
From symmetry force in the 6th chord will be same as in the 5^{th} and so on, and the constants need not be worked further.

Web Members. The force in Web Members is maximum, when the shear force in corresponding panel is maximum. Maximum positive shear in any panel occurs, when all panel points to the right of panel are fully loaded, and maximum negative shear occurs when all panel points to the left of panel are fully loaded. It is seen that this assumption is not quite

true, since it is not possible to fully load any panel point without simultaneously loading (partly) the panel points adjacent to it. However it is on the safe side and the percentage error involved is small.

Posts.

Force in n^{th} post = Shear in n^{th} panel as shown in sketch.



For maximum positive shear in n^{th} panel

the number of panel points to be fully loaded to the right = (m-n)

Effective load on the girder $= \frac{a.I.P.}{2}$ (m-n)

Distance of centre of gravity of this

load from right hand support $= \left(1 + \frac{m-n-1}{2}\right) P$

$= \left(\frac{m-n+1}{P}\right) P$

Left hand reaction $= \frac{a.I\,P.}{2} \quad (m-n) \quad \frac{(m-n+1)\ P}{2\ .\ mP}$

$= \frac{a.I.P.}{4\,m} \ (m-n) \ (m-n+1)$

Positive shear in n^{th} panel $= \frac{a.I.P.}{4\,m} \ (m-n) \ (m-n+1)$.

For maximum negative shear in the panel, all the panel points to the left are fully loaded.

Number of panel points to be fully loaded $= (n-1)$

Effective load on the girder $= \frac{a.I.P.}{2} (n-1)$

Centre of gravity of this load from Left Hand

Support $= \left(1 + \frac{n-2}{2}\right) P$

$= \frac{n}{2} P$

Right Hand reaction $= \frac{a.I.P.}{2} \ \frac{(n-1)\ nP}{2\,mP}$

Maximum negative shear $= \frac{a.I.P.}{4\,m} \ n\ (n-1)$

Maximum positive force in n^{th} post $= \frac{a.I.P.}{4\,m}(m-n)(m-n+1)$

Maximum negative force in n^{th} post $= \frac{a.I.P.}{4\,m}\; n\,(n-1)$

Considering the same span with 10 panels $(m = 10)$

Positive force in n^{th} post $= \frac{a.I.P.}{40}(11-n)(10-n)$

Negative force in n^{th} post $= \frac{a.I.P.}{40}\; n\,(n-1)$

Post.		Positive force.	Negative force.
1	$\frac{a.I.P.}{40} \times 10 \times 9 =$	$\frac{a.I.P.}{40} \times 90$	—
2	$\frac{a.I.P.}{40} \times 9 \times 8 =$	$\frac{a.I.P.}{40} \times 72$	$\frac{a.I.P.}{40} \times 21 = \frac{a.I.P.}{40} \times 2$
3	$\frac{a.I.P.}{40} \times 8 \times 7 =$	$\frac{a.I.P.}{40} \times 56$	$\frac{a.I.P.}{40} \times 32 = \frac{a.I.P.}{40} \times 6$
4	$\frac{a.I.P.}{40} \times 7 \times 6 =$	$\frac{a.I.P.}{40} \times 42$	$\frac{a.I.P.}{40} \times 43 = \frac{a.I.P.}{40} \times 12$

5 = Maximum panel point load $= \frac{a.I.P.}{2} = \frac{a.I.P.}{40} \times 20.$

There is no negative force in this post.

Diagonals.

Force in any diagonal $=$ (Shear in corresponding panel) $\times \frac{1}{h}$

Force in n^{th} diagonal $=$ Shear in n^{th} panel $\times \frac{1}{h}$

Positive force in n^{th} diagonal $= \frac{a.\,I.\,P.}{4m}(m-n)(m-n+1)\frac{1}{h}$

Negative force in n^{th} diagonal $= \frac{a.\,I.\,P.}{4m}\; n\;(n-1) \times \frac{1}{h}$

Considering the same span with 10 panels $(m = 10)$

Positive force in n^{th} diagonal $= \frac{a.\,I.\,P.}{40} \times \frac{1}{h}(11-n)(10-n)$

Negative force in n^{th} diagonal $= \frac{a.\,I.\,P.}{40}\,\frac{1}{h}\; n\;(n-1)$

Diagonal.		Positive force.	Negative force.
1 (n=1)	=	$\frac{a.I.P.}{40} \frac{l}{h} \times 90$	$\frac{a.I.P.}{40} \frac{l}{h} \times 0 = 0$
2	=	$\frac{a.I.P.}{40} \frac{l}{h} \times 72$	$\frac{a.I.P.}{40} \frac{l}{h} \times 2$
3	=	$\frac{a.I.P.}{40} \frac{l}{h} \times 56$	$\frac{a.I.P.}{40} \frac{l}{h} \times 6$
4	=	$\frac{a.I.P.}{40} \frac{l}{h} \times 42$	$\frac{a.I.P.}{40} \frac{l}{h} \times 12$
5	=	$\frac{a.I.P}{40} \frac{l}{h} \times 30$	$\frac{a.I.P.}{40} \frac{l}{h} \times 20$

The constants for any other span with different number of panels can be derived in a similar way.

WATER-SUPPLIES IN THE UNITED STATES OF AMERICA*

BY

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Synopsis.

In the United States of America, nearly 56 per cent of the population are supplied with safe water at the average rate of 100 gallons per head per day. Intermittent supplies are practically unknown. High pressures are maintained in mains. Nearly all services are metered, and there are no street stand-posts.

Rivers are freely used as sources of water. The water is nearly always purified by some kind of treatment, whatever be the source.

Application of copper sulphate to control growth of plankton in lakes is standard practice. Aeration by spray nozzles is commonly employed before coagulation and sometimes after filtration also. Aeration has lately been losing ground as a means of state and odour control.

The principles of sedimentation of colloidal floc are still imperfectly understood, and the subject is under investigation by research workers. In chemical coagulation, the trend is to separate mixing, reaction and settlement into definite stages. Optimum conditions for coagulation are studied by plant operators. Chemicals are generally fed dry. Ferric salts are coming into favour for coagulation of water, but they are fed in solution.

Activated carbon is widely used in many water plants.

Chloramine treatment is employed in some plants for taste and odour control. The ammonia is usually fed as ammonium sulphate solution. There is a new school of thought preferring "Break-point chlorination" as superior to chloramine treatment.

Pre-chlorination is standard practice for reduction of bacterial load on filters.

Slow-sand filtration is out of favour in America. Rapid-sand gravity filters are designed and built in large units. The influence of size, shape, area and distribution of sand grains on filtration and washing has been investigated, and future specifications of filter media may probably be revised after further research on these lines. Back-washing of filters is now regulated by sand expansion, instead of the rate of rise of wash-water. Air-wash is not used to any appreciable extent to assist water-wash in America. Surface-wash systems are employed to reduce wash-water consumption and keep the top layer of the filter clean.

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*An Institution Paper.

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Note :—Written comments are invited for publication.

Post-chlorination is always carried out. The water is generally finished with lime treatment to maintain carbonate equilibrium.

Softening of hard water is carried out in many public water supplies. Where lime and soda ash are used, mechanical flocculators and sludge scrapers are used. Recarbonation after excess lime treatment is generally practised.

American water plants are highly mechanised, and have excellent laboratory facilities, with trained technicians as operators.

Towns in America are empowered by State Laws to float bonds for financing public utilities. Water-supply bonds are generally attractive investment. A large number of new water plants have lately been built with liberal assistance from the Works Progress Administration of the Federal Government.

Ceylon and India are far behind the United States in water-supply and treatment. A bold national policy and a liberal Government assistance are necessary for progress.

Introduction.—The Author had an opportunity of visiting several large and small water-supplies and studying the status and technical developments in water treatment in the United States of America during his sojourn in that country in 1940. The features that impressed him most are set forth in this paper. It is hoped that they may be of some interest to other engineers and public health workers engaged like himself in solving the water-supply problems of India and Ceylon.

Population Served.—The population of the United States is about 127·5 millions (1940 estimate). Nearly 56 per cent of this is provided with protected water-supplies. Thirty-five million people were supplied with filtered water in 1934, and this figure must have increased considerably since then. Even in the comparatively less prosperous States in the South, communities of 1000 to 2000 have protected public water-supplies. Institutions like prisons and reformatories, and many temporary camps for industrial purposes or lumbering have their private supplies with sterilising plants if they are out of the reach of public water-supplies.

In intensely rural areas where the people are living on isolated farms, the County Health Engineer instals drilled wells and pumps for farmers at their request at cost price.

Nearly 80 per cent of the water-works in the United States are owned and operated by municipalities. The rest are privately owned.

The Americans generally live as concentrated groups in compact towns and villages, where urban amenities like water-mains, sewers, and electric mains can be laid at minimum

cost to serve the maximum number of people. The urban population in places of more than 2500 inhabitants was 75 millions, or approximately 59 per cent of the total population of the United States in 1934.

In Ceylon the population served by piped water-supplies is estimated crudely at 7·5 per cent of a total of 5·8 millions. About 6·5 per cent is urban population served by municipal or government supplies. The rest is estate or institutional population served by private supplies. The water is delivered in the natural state, without treatment, in many supplies. There are towns of 20,000 to 40,000 people without any public water supply. The urban population of Ceylon is only 13·2 per cent of the total. The vast majority are diffused through villages, the average rate of 254 people per village, and the size of the average village is 1·4 square mile.

In India the percentage of population served by public water-supplies is not definitely known. It is crudely estimated to be about 6 per cent. There too, towns of 40,000 exist without a public water-supply. The villages in India are more compact than in Ceylon, and have an average population of about 510.

Consumption of Water.—The average consumption of water in the United States is 100 U. S. gallons, (83·33 Imperial gallons) per head per day. Even in small villages it is about 50 gallons per head per day. In Chicago the consumption runs as high as 275 gallons per head per day. The rates of consumption in some typical American and European cities are tabulated below for comparison.

Table I. ***Rates of Water Consumption.***

American cities	Population per acre	Gallons per cap. per day.	European cities	Gallons per cap. per day.
Boston	28·5	114	Paris	97·8
Albany	10·9	150	Lyons	49·7
Buffalo	22·1	213	Cologne	32
New York	31·5	129	Munich	53·0
Atlantic	14·1	95	Berlin	20·6
Dallas	13·9	56	Vienna	14
Cleveland	24·4	143	Amsterdam	15
Chicago	24·2	275	Copenhagen	28
Kansas city	10·3	134	Manchester	34·8
Los Angeles	13·6	109	London	40·8
San Francisco	37·7	65	Edinburgh	55

Water requirements in American cities are estimated on the following basis.

	Minimum	Average
Domestic requirements	20	35
Public requirements	5	10
Commercial & Industrial	10	30
Loss by waste, etc.	15	20
Total gallons	50	95

The very high rate of consumption of water in America may be explained partly by the high standard of living of the people, and partly by the necessity for adequate protection against fire. Many buildings are built of wood. Multi-storey buildings are found even in small towns. Property is generally insured against fire risk, and the National Board of Fire Underwriters has laid down exacting standards for pressures, capacities of water mains, hydrants, and storage capacity of distribution reservoirs in water-supplies. The large number of plumbing fixtures in American houses, waste by leakage due to high pressures in mains, extreme temperature-variations prevalent in many parts of America, and the general extravagance claimed as a characteristic of the American citizen are all additional causes to the high water consumption in that country.

The hourly rate of consumption of water varies from 0·6 to 1·5 times the average in America. Water is consumed all 24 hours. There are no intermittent supplies as in India and Ceylon. An intermittent supply is considered likely to promote waste, besides being disappointing to the consumer. The hourly consumption varies over a smaller range in larger cities.

Pressures in distributing systems are maintained at 20 to 40 lbs. per square inch at street mains. Residual pressures of 75 lbs. per square inch are considered desirable for direct fire streams from hydrants.

95 per cent to 100 per cent of the house connections are metered. With a few exceptions, the installation of meters has reduced the rate of consumption of water, and tended to maintain it steady. This is well illustrated by the data regarding Springfield, Mass, in Table 2. If a supply is not metered and water is paid for at a flat rate, there is no incentive to the conservation of water, and no one can be held

responsible for the waste. The justice of paying for what one receives in strict proportion to the amount received appeals to any fair-minded person, and is the foundation of true economy. When gas and electricity are paid for by metering, there is no valid reason for not metering water. With a metered supply, any increase in consumption is translated into revenue instead of expense.

There are no street stand-posts to supply free water in American cities. This is in striking contrast with water-supplies in small towns in India and Ceylon. Many of these are designed for a consumption of 10 or 15 gallons per head per day ; the supply is intermittent, and delivered through street stand-posts ; the pressure in the street line is 2 to 3 lbs., per square inch ; the poor people wait for hours to get their daily pot of water, and collective irresponsibility results in waste through broken taps and fittings.

Table 2. ***Water Consumption, Springfield, Mass.***

Year	Average daily consumption in gallons.		Percentage of meters to services.
	per consumer	"per capita"	
1893	117	86	23·0
1898	113	89	30·0
1903	216	176	36·2
1908	124	120	50·4
1913	109	108	94·4
1918	118	116	98·0
1923	92	91	98·8
1928	98	97	99·3
1933	89	86	99·4

Sources of Water.—The large rivers of the United States are the sources for water-supply to the cities situated on them. In New England, many supplies are from upland sources, with impounding reservoirs. Cities near the great fresh water lakes, such as Buffalo, Cleveland, Detroit, Chicago, Milwaukee, etc., obtain their water by pumping from the lakes. New Orleans gets water by pumping from the Mississippi river. Columbus and Cincinnati draw their water from the Ohio river. The new water-supply to the Metropolitan water district of Southern California will be from the Colorado river by an aqueduct 241·6 miles long—a gigantic project.

Ground water-supplies from deep wells are found in rural areas of low population concentration, where geological conditions are favourable. Many small water-supplies in South Georgia are from deep wells.

Water power development is combined with water supply in some cities where gravity supplies are feasible and storage reservoirs are built.

In general, it may be said that the use of rivers for public water-supplies is widespread in the United States. It is an efficient and economical way of using the natural water resources of a country, and is capable of much wider application in Ceylon than now. Many towns in Ceylon require water badly, and the supply of water of ideal purity in the natural state from an upland source is not always practicable, even at exorbitant cost. The enormous rainfall of 90 to 100 inches per annum runs to waste through our gushing streams and rivers past thirsty towns. Rivers are more widely used in India for water-supplies.

Water Treatment vs. Conservation of Catchment.—Treatment of water to improve its quality and appearance and render it safe is almost universal in the United States of America. River water, which is so commonly used, is polluted by surface drainage and the discharge of sewage and industrial wastes. It must be purified before being supplied to cities. Even in the case of a surface supply from an unpolluted upland catchment, it is not practicable to buy up large areas, conserve the entire catchment, and safeguard the source against pollution. Purification is cheaper, and is a more efficient means of protection of the supply. Many lakes that supply water to American cities are used by the public for boating and recreation. The lakes that supply water to Columbus, Ohio, have plenty of boats at all times ; and a zoo and a recreational park are situated on the foreshore of one lake.

Control of Algae.—American lakes are subject to spring and fall overturns, with periodical changes in the growth of plankton. Water-supplies from such lakes are subject to taste and odour troubles due to plankton. These problems have received a great deal of attention from biologists and water-works operators, and their studies have added greatly to our knowledge of limnology and microbiology. Methods have been devised for the quantitative determination of odours.

Progress has also been achieved in the technique of odour control by activated carbon and break-point chlorination, besides aeration and chloramine treatment. A proper appreciation of limnetic ecology and a training in microbiology are now considered essential for the sanitary engineer or the water-works operator in America, to enable him to take an active and intelligent interest in the process of water treatment and contribute to the advancement of knowledge when he faces new problems. The researches of Hale on the New York water-supply have indicated practical measures for the control of troublesome algae in lakes by the application of copper sulphate. These have been so successful that copper sulphate treatment is now used as a standard practice in treating impounded surface water, (*e.g.* at Lexington, Ky.). It is usually applied once a week by placing the crystals in a porous sack or box and towing it behind a boat.

Aeration.—Aeration is used on many American water supplies for the removal of gases, reduction of tastes and odours due to algae or chlorine, deferrisation and demanganisation. The most popular way is to aerate the water before the addition of coagulants, through spray nozzles designed to break the water into minute droplets. The period of aeration varies from 1 to 2 seconds. On some plants aeration is employed both before and after filtration.

Influent Aerators—Providence Water-Supply R. I.

Aerators have lately been losing ground, with the realization that tastes and odours can be better controlled by the use of activated carbon, and that the complete removal of free carbondioxide is impracticable by aeration alone.

Effluent Aerators—Providence Water-Supply, R. I.

However, the aesthetic and psychological appeal of spray aerators is irresistible to the lay public, and they are useful for many other purposes besides. Over-aeration is sometimes bad for the removal of iron. The modern tendency is to enclose or cover up aerators.

Coagulation and Sedimentation.—Most American water supplies have chemical coagulation and sedimentation ahead of filtration by rapid sand filters. There are few plants employing plain sedimentation alone. The older plants have a mixing tank or channel where the coagulant is thoroughly mixed with the raw water, and a large settling tank where the floc is formed and settles down, clarifying the water. The modern trend is to separate the process into three definite stages,—mixing, reaction and settlement, carried out in three separate tanks of appropriate design.

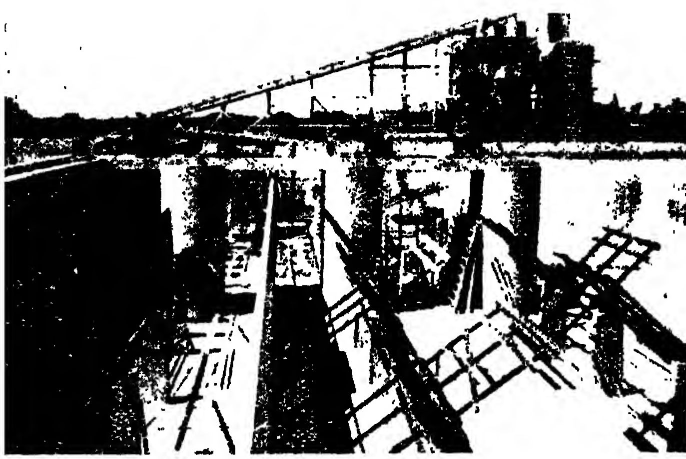
The mixing is accomplished in baffled tanks, rotary flow tanks, or channels with hydraulic jump. The loss of head is 1 to 3 feet. The rotary flow tanks are operated with an influent velocity of over 5 feet per second and an effluent velocity of

under 4 feet per second, both being tangential to the circular periphery. Such a tank is used at Providence. The hydraulic pump is used for mixing at Cleveland, Ohio.

Mixing is also done by rotating paddles driven by motors, by compressed air, and by centrifugal pumps in some plants.

The flowing-through time in mixing tanks is 1 to 3 minutes. Rotating paddles are driven at 1 to 8 r.p.m.

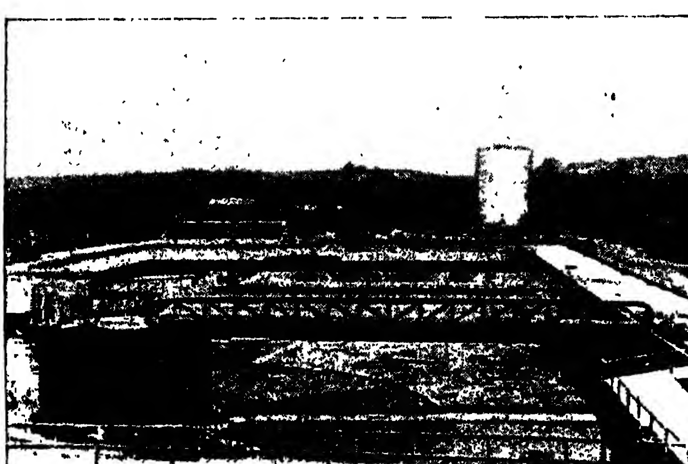
Reaction chambers are designed for a flowing-through time of 10 to 60 minutes. The velocity is ·5 to 1′ per second. These are fitted with baffles, or designed as channels, or fitted with mechanically driven paddles. The last type is common in softening plants (Columbus and Cincinnati) and is considered flexible and compact.



New Water Softening Mechanical Flocculators Treatment Plant, Los Angeles, U.S.A.

Settling tanks have detention periods varying from 2 to 8 hours depending upon the nature of the water, dosage of chemicals, temperature, etc. With mechanical flocculators, the detention period is materially reduced. Common horizontal velocities are 7 to 15 mm. per second. The tanks are usually open, and columns are avoided in the construction to reduce dead spaces and eddies. The commonest type is the horizontal longitudinal flow tank, equipped with a multiple opening baffle at the inlet end and weir at the outlet end, with few baffles in between, and operated continuously. Hopper bottoms are not used to any great extent.

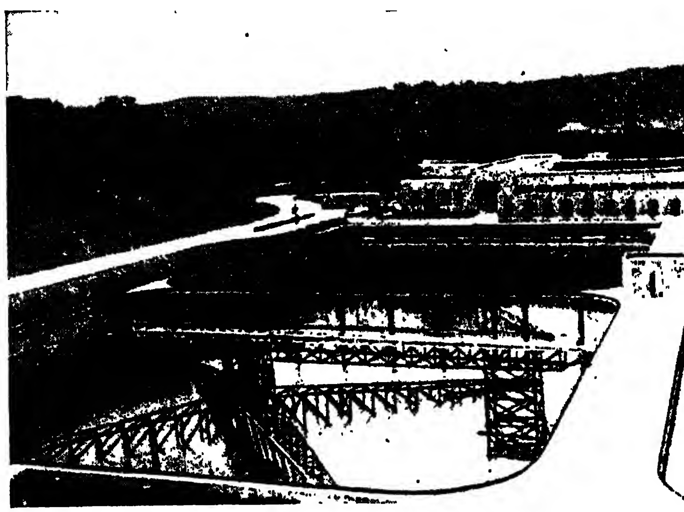
Hazen's theory of sedimentation holds the field, in spite of the fact that his assumptions are not wholly applicable. All particles are not mineral matter, and all do not have the same hydraulic value. He does not take into account the effect of aggregation of particles, which is so important in flocculation. Moreover, the shape of the tank and the arrangement of baffles influence the flow lines and the time of flow of individual streams of liquid. These limitations on the applicability of Hazen's theory are recognised, and a great deal of research has been done in recent years on flow through model tanks. Prof. T. R. Camp of the Massachusetts Institute of Technology has investigated the question of settlement of particles of different hydraulic subsidence value. The effects of coagulation and aggregation are not known. Little is known about the removal of particles by sedimentation in a radial flow tank, or a tank where the effluent is taken away by a series of weirs at varying distances from the inlet. Model studies indicate that the actual flowing-through time in a horizontal tank may be much shorter than the conventional "Detention time". Multiple opening inlets are said to be better than weir inlets.



Mech. Scrapers for sludge removal, water softening.

Settling basins are often constructed taking advantage of natural depressions in the ground, and no lining is provided unless it is considered absolutely necessary. Sludge removal is effected in lined tanks by underdrains, and where the sludge is considerable (as in the softening plants at Columbus and Cincinnati) it is removed continuously by mechanical scrapers.

Chemicals and Dosing Equipment.—Progress in the knowledge of colloidal chemistry has led to a better understanding of the process of removal of colour and colloidal turbidity by chemical coagulation under optimum conditions. Dosages are



Cincinnati Water Purification Plant Sedimentation tanks.

determined daily through experiments by plant operators. Though alum and lime are the most widely used coagulants, ferric salts are coming more and more into favour, because of their efficiency over a wider range of pH, and their greater suitability for the removal of colour and iron. Difficulties in the use of ferric salts have been overcome by rubber-lining of tanks. Ferric chloride is used now instead of alum at Providence. Milwaukee is using ferric chloride for half the plant and alum for the other half.

Alum, lime and activated carbon are supplied to standard specifications as powder in paper bags, barrels or in bulk. Paper bags are piled on the floor, and chemicals in bulk are stored in bins. Most modern plants feed alum, lime and activated carbon dry, through dry-feed machines. Ferric chloride and chlorinated copperas are always fed in solution.

Special dust-control devices are used in connection with the handling of activated carbon and lime. Ventilating systems are designed, and suction feeders are used for transferring dusty chemicals in bulk from railway wagons to bins.

Activated carbon is very widely used in water treatment in America. The equipment for feeding carbon is always included in the design, whether it is proposed to use it

A dry feed machine for alum, lime and activated carbon.

immediately or not. The usual point of application of carbon is in the mixing tank, but it is sometimes applied in the clear water channel from the settling tank to the filter house.

Pre-chlorination and Chloramine Treatment.—Almost every modern water plant is designed for chlorination before filtration. Supplies from the great lakes and rivers are generally pre-chlorinated, to reduce the bacterial load on the filters. In many supplies subject to tastes and odour troubles of algal origin chloramine treatment or break-point chlorination is adopted.

For chloramine treatment the ammonia is usually fed as ammonium sulphate solution, and occasionally as gaseous ammonia, ahead of the chlorine. There are two water plants in Cleveland, one using chloramine treatment, and the other using break-point chlorination for control of tastes and odours. Residual chlorine of 0·4 to 0·5 p.p.m. is maintained. Mr. Maxwell, the Superintendent of the Cleveland waterworks believes that break-point chlorination is superior to chloramination for controlling algal and chlorophenolic tastes.

Perhaps the term "Break-point chlorination" requires some explanation, as it is very new in waterworks practice. When a water containing organic matter is chlorinated and the dosage of chlorine is gradually increased, the residual also increases correspondingly up to a certain stage, and then drops suddenly. If the curve of residual chlorine is plotted against chlorine dosage it shows a sudden break at this stage. Chlorination up to this stage is called break-point chlorination, and it effects complete oxidation or "burning up" of organic matter, thereby getting rid of tastes and odours of algal origin. It is different from super chlorination as ordinarily understood because there is no dechlorination afterwards. In break-point chlorination a residual is maintained after reaching the break-point.

Filtration.—There are not many slow-sand filters in America. They are found occasionally in some old plants, but their numbers have been decreasing steadily since 1914. Some water-supplies have given up their old slow-sand filters and built new rapid filters. Slow-sand filters are becoming obsolete.

The use of pressure filters is confined to small supplies for swimming pools, and industrial supplies, etc.

Rapid sand gravity filters may be said to have been developed in America. They are very widely used. They are built by city engineers to their own design or the design of their consultants.

The filter units are comparatively large in size, varying from ·01 to ·1 acre. There is a certain amount of variety and originality in the design and arrangement of wash-water gutters, underdrains, etc. Out of the variety of experience gained from several plants there has been evolved a special branch of applied hydraulics covering all the elements of

filter design. Some of the formulae are empirical, but many others are rational. The design and construction of rapid filters is not a mystery belonging to patent holders.

The depth of the filter bed is generally made up of 27 to 36 inches of selected sand over 12 to 18 inches of selected gravel. 30 inches of sand and 18 inches of gravel are commonly used. The sand has an effective size of ·35 to ·6 mm., and a uniformity coefficient of about 1·5. Most plants use sand of effective size ·45 mm., and the tendency is to increase the size.

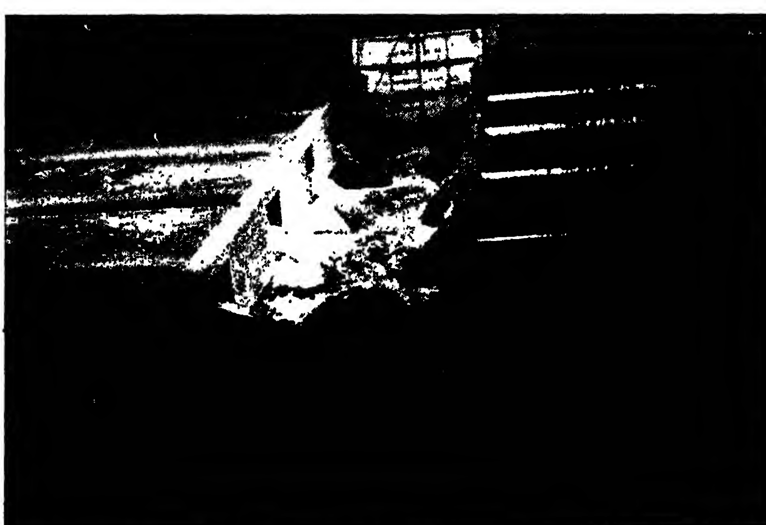
Hazen's familiar definition of effective size and uniformity coefficient have been accepted till recently as the basis for specifications of filter media in most filter plants. But these are now criticised. It is considered necessary to specify the upper and lower limits of size. Statistically it is better to specify the mean grain diameter and the standard deviation. The diameter of sand grains is hard to measure, but can be measured in various ways. The shape and surface area of sand grains have to be considered, not merely the sieve opening they pass through. These affect their hydraulic subsidence value, and hence the operation of the filter, also the head lost in filtration and washing. These questions have been investigated by Prof. G. M. Fair and his associates of the Harvard University. He has developed rational, though complicated formulae for the hydraulics of filtration and washing, based on the porosity, mean diameter and standard deviation, area-shape and volume-shape factors of the sand grains. The measurement of the area of sand grains is indirect and still imperfect. But the importance of these factors is now appreciated, and Prof. Fair's investigation has already opened a new method of approach to problems of seepage of water through sands in soil mechanics. Future research may bring about radical alterations in the methods of specifying and measuring filter media.

Professor Fair has also investigated what he calls the "Critical depth" in filters, *i.e.*, the depth to which turbidity will penetrate under normal rates of flow in filter beds. He finds that only the top 8 or 9 inches in a rapid sand filter is concerned in the removal of turbidity and bacteria, and is of opinion that a 30 inch deep bed is too deep, even after allowing a margin of safety over the critical depth.

There are few filter plants in America using the air-wash combined with water-wash. Backwashing with water is the

usual way. Loosening of a dirty sand bed by rakes on a revolving arm is not practised to any appreciable extent.

The old method of backwashing filters at a set rate of flow (commonly 24" rise per minute) is now being superseded by the more rational method of regulating the wash-water to obtain about 50 per cent expansion of sand. In colder weather the wash-water will have a lower temperature and a greater viscosity. Hence its lifting power will be greater, and if the velocity of wash is not regulated some sand may be lost through the gutters. In hot weather the wash-water will be less viscous, and may not lift the sand sufficiently to get rid of the slimy dirt, unless the velocity of wash is increased to obtain the necessary sand expansion. Water-works operators in America are now regulating their wash-water to obtain 40 to 60 expansion of sand. They find the expansion either with the aid of a floating device, or by eye. The duration of a wash is generally 5 minutes, and the filter bed is out of commission for about 15 minutes.



Surface-Wash in operation in filters—Milwaukee Water-Works.

A recent development is the system of surface washing, *i.e.*, the application of wash-water at or near the surface of sand in the filter. It loosens the dirt in the layer of sand actively concerned in filtration. Many different schemes of surface wash are in use. In one system the wash-water is delivered

through a series of jets directed at 38° to the vertical from a series of pipes fixed 4" above the sand. The downward jets disturb and swirl up the sand. At Buffalo another system is being tried, and the wash-water is applied through a lawn sprinkler type of rotary arm. The surface wash is used alone when the filter is only moderately clogged, and in conjunction with sub-surface wash when badly clogged. By the use of surface wash, plant operators are able to economise in wash-water, and get longer filter runs from cleaner beds.

Wash-water is generally applied at a pressure of about 15 lbs. per square inch at the strainer system. In unavoidable situations this pressure is obtained by direct pumping instead of by gravity. Large wash-water pumps for direct pumping are expensive.

Though every filter plant has a filter-to-waste connection for rejecting the filter effluent for a short time immediately after washing, it is never used in practice. Many operators are of opinion that it is unnecessary.

Filter runs generally vary from 30 to 48 hours in plants treating the water from the great lakes.

Hydraulic sand ejectors are used in washing the sand in slow sand and iron removing filters.

Sand washing by Hydraulic Sand Ejectors Lowell Water-Works.

One of the most impressive features in an American filter plant is the beautiful operating table where all the controls are assembled together for finger-tip manipulation. Most of the valves are operated hydraulically or electrically. The operator can observe what is happening in any filter, and control everything from one spot with the ease with which one would switch on a lamp in the most modern plants.

Post-Chlorination.—Filtration is considered only a part of the purification process, and the water is always finally sterilised by chlorine. In this connection it is worth recalling an occurrence that took place in Milwaukee in 1916. The attendant at the Milwaukee water-works stopped chlorination for 8 hours on a certain day, when the water happened to be badly polluted. The result was 50,000 to 60,000 cases of enteritis, 400 to 500 cases of typhoid, and 40 to 50 deaths in the city. The dangers of interrupted sterilisation are not sufficiently realised by the untrained and uneducated operators in small water-supplies in India and Ceylon. Some of the chlorinator installations are badly designed, and the supply of solution water entails frequent pumping by manual labour that could have been saved by a small extra outlay on machinery. The attendants have a strong temptation to close down the chlorinator in such circumstances. Residual chlorine tests are not run daily by many attendants. In some installations the tests are never run.

In America liquid chlorine is used in all but very small supplies. The chlorine is generally fed into the water as a solution, not as gas. Absorption towers are not used for making up solutions.

Large chlorinator installations are equipped with the means of controlling temperature in the cylinders, the machines, and the room. They are also equipped with ventilating systems. The air that is taken out of the room is forced through a series of screens in a box into which a caustic spray can be turned on to absorb free chlorine if there is a leakage. The spray can be operated by a switch outside the room in an emergency. The sewage treatment plant at Detroit, Michigan has a very modern chlorinator installation, with 9 chlorinators each capable of feeding 6000 lbs. of chlorine per day, and equipped with the latest safety devices.

Finishing Treatment for Corrosion Control.—In many water-plants in America the filtered and chlorinated water is dosed

with lime to maintain carbonate equilibrium and render it non-corrosive. The Langelier index is maintained less than -0·5. The correct determination of the dosage of lime necessary for this purpose has been made easy by the method of Professor Moore of the Harvard University. In some plants secondary aeration is carried out before lime treatment.

The maintenance of carbonate equilibrium by a finishing treatment with lime is desirable in Ceylon, where many waters are acidic and corrosive.

Softening.—Some 126 public water-supplies in the United States soften the water. Thirty-four of these are in the State of Ohio. The Chain of Rocks plant at St. Louis, Missouri is the world's largest softening plant with a capacity of 160 million gallons per day. The new softening plant for the Metropolitan water district of Southern California will have a capacity of 100 m.g.d. initially and 400 m.g.d. ultimately. Both lime and zeolite will be used in this plant to reduce the hardness from about 400 p.p.m. to about 85 p.p.m.

Municipal softening plants usually reduce the carbonate hardness to about 35 p.p.m. and the non-carbonate hardness to about 50 p.p.m.

In plants employing the lime soda process the two chemicals are mixed together and fed as one solution, or applied separately near each other. Dry-feed is becoming more and more popular. Mixing of chemicals is usually carried out by mechanical flocculators. The mixing and settling time are usually longer than in ordinary coagulation and filtration plants. Settling tanks are usually equipped with Link-belts or rotary scrapers for continuous removal of sludge in softening plants employing the lime soda process. In order to reduce the time for reaction and produce a water of lower residual hardness excess lime or soda ash treatment is employed. The effluent from the settling tank is then recarbonated, to neutralise caustic alkalinity and prevent incrustation of sand grains in the filter beds and incrustation in pipes.

Recarbonation is carried out generally in the following manner. Coal, oil, or gas is burned in a furnace, boiler or engine, and the carbondioxide which is produced is passed through a scrubber and a drier. It is then forced by a blower through nozzles or grid openings placed below the surface of the water. The carbondioxide is added to produce a

water of pH 9·4 to 9·6, so that the maximum amount of calcium carbonate may be thrown out as precipitate and held on the filters. In some small plants the recarbonation of water is carried out by burning coal gas under water.

In the new softening plant for the Metropolitan water district of Southern California it is proposed to burn the precipitate of calcium carbonate and recover the lime for re-use.

Deferrisation and Demanganisation.—Removal of iron and manganese are effected in many plants by aeration and slow-sand filtration, with contact beds and sedimentation tanks in between. Spent zeolites are used sometimes for iron removal; also special zeolites are used for manganese removal in industrial treatment. Lime is used in closed systems sometimes for removal of iron. Straight coagulation with iron salts at high pH values is used for deferrisation at Providence.

Aerators for deferrisation Lowell Water-Works, Mass.

Plant Control.—A very pleasing feature in almost every water plant in the United States of America is the mechanical equipment reducing manual labour to a minimum. Valves are hydraulically or electrically operated. Pumps are generally electrically driven. Sand-washing in slow sand filters is done by hydraulic ejectors. Submerged electric lamps in mixing tanks and filters indicate the character of the floc and the

expansion of the sand respectively. Unloading of dusty chemicals and raising them to bins is done by pneumatic equipment. Other chemicals are raised to the storage room by elevators. As many adjustments as possible are made automatic. Meter readings, weights and other data are recorded automatically wherever possible. Sampling taps are provided at convenient points. Every place is accessible.

Sampling Taps in the Water-Works Laboratory, Detroit, U.S.A.

Perhaps the finest feature in American water plants is the complete laboratory for routine chemical, physical and bacteriological examination. The water is examined daily by the staff, and a consistently high standard of purity is maintained. Trained technicians study their waters and the treatment process every day in these laboratories. They are able to conduct researches and contribute to the advancement of knowledge. In these respects water-plants in India and Ceylon are very far behind. Small plants have no laboratories at all, and operators are untrained men who know only the mechanical part of the plant. There is no plant control. Samples of water are sent to the Government laboratories hundreds of miles away at intervals of several months or years. Heavy charges are levied at these laboratories for analysis of water for municipalities and private bodies. We should have more and better laboratories. Water-works operators should be

men with at least an elementary knowledge of the process of water purification, and they should be trained to check the efficiency of the plant and make the necessary adjustments. They should be able to run tests on the water in the larger plants. The absence of such men is partly responsible for the absence of a demand for high grade chemicals in India and Ceylon for water treatment. In Kentucky, U.S.A. they have a system of licensing of small water-works operators by the State after a short course of theoretical and practical training and examinations. The larger water plants employ expert scientists and engineers.

Finance.—It may be wondered how American villages and towns are able to finance their water schemes when even large cities in India and Ceylon find it very difficult to obtain funds for similar purposes.

In the first place the American people have a better appreciation of the benefits of such schemes. The promotion of a new water-supply is therefore much easier, and is further facilitated by the tradition of efficient service and abundant and pure supply of water in existing water-works.

The capital investment is usually derived from borrowed money. The water-works of America have an enviable financial record, and securities are usually attractive to investors.

Public and municipal water-supplies are subject to State laws for raising money. Some or all of the following procedures are available to them.

General bonds can be issued for such purposes by the city up to a limit, and secured by the real property of the community. In Georgia, water-works bonds can be floated up to 7 per cent of the assessed value of property of the entire community served. In some States it is secured by the general tax or mileage paid by the community.

Special lien bonds can also be issued by a city, payable out of the revenue derived from the particular public utility. Such bonds will be available for water-works and electric supplies but not for sewer projects, as they do not produce any direct revenue. Direct taxation and special assessment are rarely used for financing water-supplies in America.

In some States neighbouring municipalities are permitted to organise themselves into a water district for issuing bonds to finance joint water projects, etc.

Sometimes when a municipality has already exhausted all its powers to float bonds up to the full legal limit, it can arrange for a private joint stock company to finance the required improvements and use the new revenue from the sale of water to buy up the entire concern gradually.

Since 1932, many public water-supplies have received grants and other aid from the Federal Government. The R.F.C. (Reconstruction Finance Corporation) created in 1932 by the Roosevelt Administration enabled public agencies to borrow money from Government for schemes designed to relieve unemployment, provided the schemes were self-supporting, revenue-earning, and financially sound. The P.W.A. (Public Works Administration) created in 1933 enabled the President of the United States to make grants up to 45 per cent of the cost of labour and materials employed in such projects, and to finance the remainder by secured loans. This was also meant to relieve unemployment.

The W.P.A. (Works Progress Administration), also part of the New Deal of the Roosevelt Administration, enabled the Federal Government to meet the cost of labour and give grants for any useful public project such as water-supply, malaria control, sewerage, drainage, highway improvement, etc., provided the local body concerned paid for the materials, found the necessary tools and plant to hire to the W.P.A., and gave employment to the unemployed in the area. Under the stimulus of the liberal federal assistance of the W.P.A., an enormous number of water-supply and purification projects have been completed during the last 8 years.

In India and Ceylon our cities and towns are crippled financially. The people who run the local government are unable and unwilling to undertake water-supply schemes without Government grants and loans. It is desirable for Government to initiate a bolder national policy of financial assistance for such schemes, so that the foundation of national health may be well laid, unemployment may be relieved, industrial enterprise may be stimulated, and the standard of living of the people may be raised.

Water treatment plants inspected by the author in the U.S.A.

1. Lowell water-works, Mass.
2. Salem-Beverly water-works, Mass.
3. Lawrence water-works, Mass.

Water treatment plants inspected by the author in the U.S.A. (Contd.)

4. Providence water-works, R.I.
5. Buffalo water works, N.Y.
6. Cleveland water-works, (2 plants,) Ohio.
7. Detroit water-works, Michigan.
8. Chicago water-works, including the new one under construction.
9. Milwaukee water-works, Wis.
10. Cincinnati water-works, Ohio.
11. Columbus water-works, Ohio.
12. Lexington water-works, Ky.
13. Carrolton water-works, Ky.
14. Dublin water-works, Ga.
15. Haxlehurst water-works, Ga.
16. La Grange reformatory water-supply, Ky.
17. New Orleans water-works, La.
18. Metropolitan water district of South California water softening plant, Los Angeles.

References.

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2. Hoover,—Water-supply and treatment (1938)
3. Whipple,—Microscopy of drinking water.
4. American water-works Association,—Water works practice.
5. Fair, G.M.—Notes of lectures in the Harvard Engineering School.
6. Fair, G.M.—On the determination of tastes and odours, (Harvard Engineering School publications)
7. Moore, E.W.—Notes of lectures in the Harvard Engineering School.
8. Moore, E.W.—Calculation of chemical dosages required for corrosion control (Harvard Engineering School publications)
9. Thomas, H. A. Jr.—Notes of lectures in the Harvard Engineering School.

DESIGN OF "MONOLITHIC ARCH" OF ANY SHAPE WITH CONSTANT OR VARYING MOMENT OF INERTIA

BY

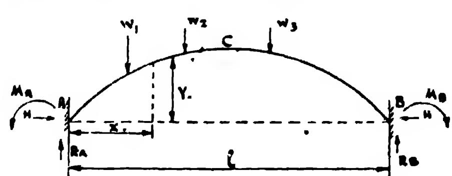
V. VENKATARAMAYYA, A.M.I.E.*

Synopsis.

The determination of stresses in a Monolithic Arch by purely analytical methods is a laborious process, and very often recourse has to be made to graphics for solution of some of the integrals. For arches in Masonry and plain concrete, Fuller's graphical method is convenient, but is not applicable to Reinforced concrete Monolithic Arches. The method described in this paper is applicable to any Arch, with ends fixed or hinged or tied as in Bow-string type.

The Monolithic Arch is one of the oldest types of bridge construction but the determination of stresses has been a laborious process involving solution of several complicated equations. It is intended to present in this paper, a method which is partly analytical and partly graphical and which can be easily applied to any problem on arch design.

A C B is the profile of an arch, with ends encastre at A and B, and w_1, w_2, w_3, etc. are the external loads.



Let M_A be the fixing moment at A, M_B at B, and H the horizontal thrust. The arch may be now considered as resting freely at A and B and acted upon, by loads, w_1, w_2, w_3, etc., external couples M_A and M_B and horizontal forces H. The resultant bending moment at any section of the arch is obtained by superimposing the bending moment, for each of the above group of forces acting separately.

*Asst. Bridge Engineer, B. N. Rly., Calcutta.

Note.—Written comments are invited for publication.

Considering a section of the arch at a distance X from A, the bending moment at this point is made up of four components.

(1) M_w due to external loads acting alone

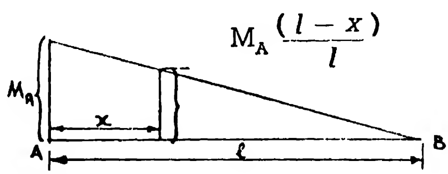
(2) L M_A due to fixing moment M_A

(3) βM_B due to fixing moment M_B

(4) H Y due to horizontal thrust.

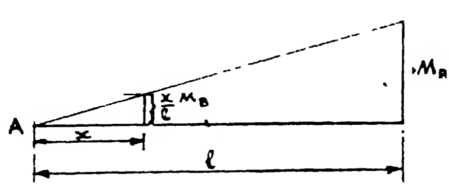
M_w is the free bending moment, is easily found out either by calculation or graphically.

α M_A is the bending moment due to end fixing moment M_A acting alone. It can be seen that due to M_A, the bending at any section at a distance X from A is $M_A \frac{(l-x)}{l}$ where l is the span.



Thus α is a fraction and is easily calculated or measured. If the ordinate at A is unity, then the ordinate at any other corresponding point is α.

Similarly, due to end fixing moment M_B acting alone the bending moment at section is $\frac{x}{l}$ M_B or βM_B and β is also known.



Bending moment due to horizontal thrust H acting alone, is HY at the section. Therefore the resultant bending moment at section X $= (M_w + L M_A + \beta M_B HY)$. If M is the resultant bending moment at any section and α the bending moment at that section due to unit couple alone acting at A, the change of slope at A is given by $\leq \frac{M\alpha\, \delta s}{EI}$ Also from

the conditions of end fixation, there can be no change of slope at A and B and no change in the length of span. Considering the arch is made up of a number of small sections δs, the change of slope at A

$$=\sum \frac{\alpha (M_w + \alpha M_A + \beta M_B + HY)\delta S}{EI} = O$$

change of slope at B $\quad \sum \frac{\beta(M_w + \alpha M_A + \beta M_B + HY) \delta S}{EI} = O$

change in length of span $= \sum \frac{y (M_w + \alpha M_A + \beta M_B + HY) \delta S}{EI} = O$

The arch is divided into a number of equal segments say 10, 15, or 20, depending on the degree of accuracy required and at the centre of each segment, the values of M_w, α, β, and y are determined.

The three equations are then formed as shown in the example below, and from these M_A, M_B and H are evaluated, since all other terms are known. If I is constant throughout the arch, it can be omitted, but if it is varying, $\frac{\delta S}{I}$ is to be worked out for each section or segment concerned and then the summation obtained for the whole arch.

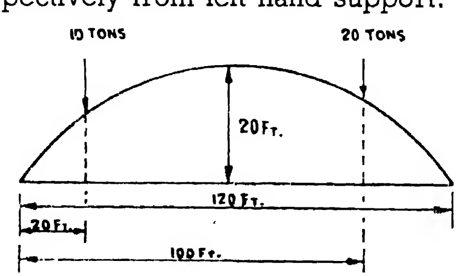
***Example* :—**

Segmental Arch Fixed at both ends

Span = 120 ft.

Rise = 20 ft.

External loads: 10 Tons and 20 Tons at a distance of 20 ft. and 100 ft. respectively from left hand support.



The arch is divided into 20 equal segments and at the section corresponding to the centre of each segment, vertical lines are drawn as shown in sheet No. 1, and the values of M_w, Y, α, β, and H are measured and tabulated.

From the three equations

$$(1)\quad \Sigma\alpha M_w + \Sigma\alpha^2 M_A + \Sigma\alpha\beta M_B + \Sigma\alpha Y H = O$$

$$(2)\quad \Sigma\beta M_w + \Sigma\alpha\beta M_A + \Sigma\beta^2 M_B + \Sigma\beta Y H = O$$

$$(3)\quad \Sigma y M_w + \Sigma\alpha y M_A + \Sigma\beta y M_B + \Sigma Y^2 H = O$$

$\Sigma\alpha M_w$, $\Sigma\alpha^2$, $\Sigma\alpha\beta$, etc., are obtained by summing up the respective columns in the table I and the equations are formed. Adopting the usual convention for signs, M_w is taken as negative.

$$-2268{\cdot}3 + 6{\cdot}75\, M_A + 3{\cdot}25\, M_B + 132\ H = 0$$

$$-2626{\cdot}8 + 3{\cdot}25\, M_A + 6{\cdot}75\, M_B + 132\ H = 0$$

$$-74331{\cdot}0 + 132\, M_A + 132\, M_B + 4195\ H = 0$$

M_A = 12·56 Tons-inches
M_B = 115·0 Tons-inches
H = 13·7 Tons

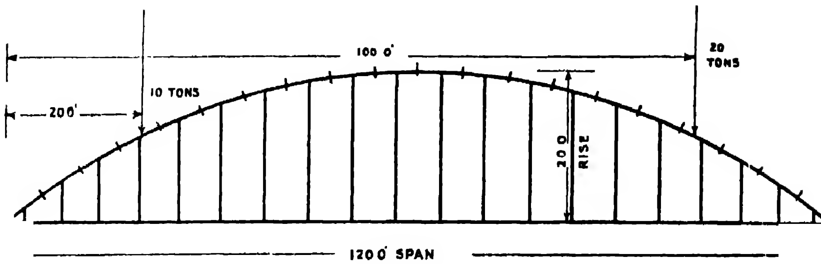
Knowing M_A, M_B and H, the bending moment, thrust and shear, at any section of the Arch can be easily determined. For example the bending moment under 10 Ton load is

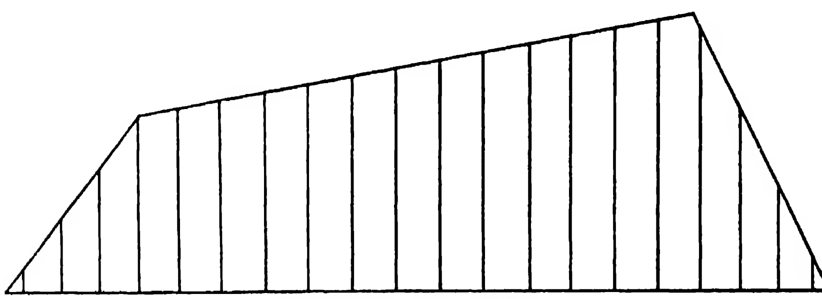
$$-233{\cdot}4 + \frac{100}{120} \times 12{\cdot}65 \quad \frac{20}{120} \times 115{\cdot}0 + 13{\cdot}7 \times 11{\cdot}5$$

$$M_w + \alpha M_A + \beta M_B + H Y$$

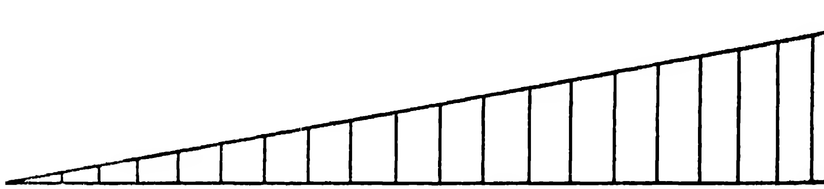
$$= -233{\cdot}4 + 10{\cdot}54 + 19{\cdot}17 + 157{\cdot}55$$

$$= -45{\cdot}88 \text{ Tons ft. Units.}$$

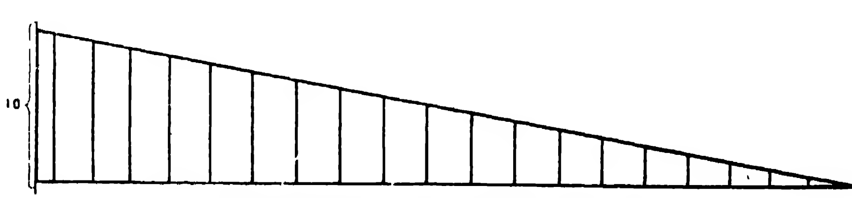




FREE BENDING MOMENT DIAGRAM



BENDING MOMENT DUE TO UNIT COUPLE AT B



BENDING MOMENT DUE TO UNIT COUPLE AT A

TABLE I

1	2	3	4	5	6	7	8	9	10	11	12	13
Serial No.	M_w	α	β	y	αM_w	α^2	$\alpha\beta$	αY	βM_w	βY	YM_w	Y^2
1	33	·98	·02	1·8	32·3	·960	·020	1·76	0·7	0·04	59·0	3·2
2	95	·93	·07	5·4	88·4	·865	·065	5·02	6·6	0·38	513·0	29·2
3	159	·88	·12	8·5	140·0	·774	·106	7·48	19·1	1·02	1352 0	72·3
4	226	·84	·16	11·4	190·0	·706	·134	9·58	36·2	1 82	2576·0	130·0
5	242	·79	·21	13·7	191·3	·624	·166	10·82	50·8	2·88	3315·0	187·7
6	253	·74	·26	15·7	187·5	·548	·192	11·62	65·7	4·08	3972·0	246·5
7	263	·68	·32	17·5	179·0	·462	·218	11·90	84·1	5·60	4600·0	306·3
8	273	·63	·37	18·6	172 0	·397	·233	11·72	101·1	6 88	5080·0	346·0
9	284	·58	·42	19·5	164·8	·336	·244	11·31	119·4	8·19	5535·0	380·3
10	294	·53	·47	19 9	156·0	·281	·249	10·55	138·3	9·35	5850·0	396·0
11	305	·47	·53	19 9	143·5	·221	·249	9·35	161·8	10 55	6070·0	396·0
12	316	·42	·58	19 5	132·8	·176	·244	8·19	183·4	11·31	6165·0	380·3
13	327	·37	·63	18 6	121·0	·137	·233	6·88	206 0	11·72	6080·0	346·0
14	337	·32	·68	17 5	108·0	·102	·218	5 30	229·0	11·90	5900 0	306·0
15	348	·26	·74	15 7	90·5	·068	·192	4 08	257·5	11·62	5460·0	246·5
16	358	·21	·79	13·7	75·2	·044	·166	2·88	283·0	10 82	4900·0	187·7
17	350	·16	·84	11·4	56·0	026	·134	1·82	294·0	9·58	3990·0	130·0
18	243	·12	·88	8·5	29·2	·014	·106	1·02	214·0	7·48	2066·0	72·3
19	142	·07	·93	5·4	9·9	·005	·065	0·38	132·0	5·02	767·0	29·2
20	45	·02	·98	1·8	0·9	·000	·020	0 04	44·1	1·76	81·0	3 2
Summing up the respective Columns.					2268·3	6 750	3·250	132·00	2626·8	132 00	74331·0	4195·0
					$\Sigma\alpha M_w$	$\Sigma\alpha^2=\Sigma\beta^2$	$\Sigma\alpha\beta$	$\Sigma\alpha Y$	$\Sigma\beta M_w$	$\Sigma\beta Y$	ΣYM_w	ΣY^2

ELECTRIC WAVE FILTER THEORY AND ITS APPLICATIONS[1]

DISCUSSIONS

Annual General Meeting[2]

Dr. Shiv Narayan[3] in introducing the paper said that he would show some illustrations and diagrams pertaining to the subject on the board by means of epidiascope and optical lantern, so that members would be better able to follow the discussion on the paper. He then explained the theory as propounded by the Author of the paper by means of slides, and a radio demonstration was also given to show that by the rejector circuit the hissing noise and disturbances could be removed. He then went on to define "Electric Wave Filter" and said that it was time that we understood electric wave filter as we did water filter. Water and Electricity were closely allied one to the other. Hydraulic Engineers were familiar with water filters which were appliances for separating suspended particles from a liquid. Similarly an electric wave filter might well be defined as an apparatus containing a network of circuits for separating signals of certain frequencies from those of other frequencies. Filters were of two kinds (i) a periodic or non-resonant, comprising of circuit containing R and L or R and C usually employed to prevent interference directly or indirectly due to natural causes e.g., atmospherics and (ii) periodic or tuned, largely consisting of L and C ordinarily used to prevent amplification of signals from transmitting the stations other than those from the station to be received.

A circuit having L and C connected in parallel and so adjusted as to produce parallel resonance offered very large impedance and allowed very small currents to flow and was therefore called a rejector circuit. Such a circuit in parallel with an acceptor circuit (one having R, L and C in series so adjusted as to produce resonance) should be tuned to same

1. This paper by Mr. S. N Mukerjee, A.M.I.E was published in the Journal Vol. XXI No. 2.
2. Discussion at the Annual General Meeting on 4th February, 1941 at Poona.
3. Professor, Muslin University, Aligarh (Retd.I.E.S.)

frequency, as that of wave to be received, so as to reject or by-pass this wave but allow others to go through. If it was connected up as a separate circuit and brought close to coil in aerial circuit and thus inductively coupled to it, the same effect would be produced in the radio receiver coupled to another coil in the aerial circuit. These effects, he explained, had been demonstrated at the outset of these remarks. Tuned filter was good for differentiating between two continuous signals of nearly the same frequency. The circuit diagrams of non-resonant and resonant filters had been shown by means of the Epidiascope. Besides statics and strays, interference was due to various other causes e.g., spark plugs of automobiles (particularly of old lorries), sparking at commutators of dynamos, traction lines, tram lines, power lines, tape machines, tightly coupled transmitters, quenched spark systems and others, emitting heavily damped waves. Interference was also caused by harmonics of wave to be received. Aerials of radio receivers should be fixed so as to be at right angles to power lines and fitted with suppressors. Regarding traction system, the following sentence from the recent book on "Electric Railway in India" was relevant to the subject under discussion :—

"In the Bassein Road railway sub-station of the B. B. & C. I. Railway, harmonic suppressing devices are employed, each consisting of one main reactor and periodic filters tuned for 600 and 1,200 cycles. In the South Indian Railway traction sub-station, suitable wave filters equipments tuned for 300, 600, 900 and 1,200 cycles have been installed to eliminate interference with telephone and other communication circuits." Ordinarily batteries were employed to furnish currents for filament and plate circuits of amplifiers but generations provided with suitable filters could be employed as ripples due to commutator-sparking were cut out by the filters. Filters were also employed to suppress resonance in loudspeakers or to control the tone. They were also used to measure the performance of sets.

Dr. Shiv Narayan then referred to p. 323 wherein the Author had stated that the most practicable way of approaching the relation LG = CR was to "load" the circuit inductively and said that it was not strictly true. Mr. Oliver Heaviside suggested (besides loading telephone lines for increasing the efficiency of transmissions) increasing the leakage *i.e.*, "G." This suggestion was rediculed, but an accident occurred causing leakage and improved the transmission. Prof. Pupin of

America used inductance coils for local loading of the lines for the same purpose, 10 coils being used per wave length. Inductance is increased uniformly if the wires are coated with permalloy.

Mr. N. V. Modak[4] thanked Dr. Shiv Narayan for introducing the paper in the absence of the Author and for explaining the various details and proposed a hearty vote of thanks to the Author for his interesting paper.

Mr. S. P. Chakravarti[5], *M.Sc., D.I.C. (Lond).* (by letter) stated that the paper entitled "Electric Wave Filter Theory and its Applications" by Mr. S. N. Mukherjee related to matter taken entirely from works of well-known authors on the subject which had been established beyond doubt to need further discussion as to their technical merits.

Even as review of the developments and applications of electric wave filters *upto date*, the paper left much to be desired.

Under the section—"The problem of the Loaded Transmission Line and the Evolution of the Electric Wave Filter" (p. 323), the treatment was incomplete without showing characteristic impedance—frequency and phase-shift—frequency characteristics for loaded and non-loaded cable circuits. Further, a discussion of the "transient phenomena" associated with loaded lines and wave-filters near about the cut-off point should have been included as they had received considerable attention in the design and operation of long distance cable circuits abroad.

Under the section—"Theory of Electric Wave Filters" (p. 326), mention of π type sections had not been made. The Author would no doubt appreciate that full sections and half-sections of π type were commonly used in the design of filter-networks for various systems. *The same condition* for unattenuated transmission could be deduced for such section as well, provided total series and shunt impedances in T and π sections remained the same.

Under the section—"Types of Wave-Filters" (p. 328), the Author mentioned at the end of the last paragraph that "the consequences of ignoring ohmic losses in design calculations

4. President of the Institution of Engineers, (India).

5. Professor, Science College, Calcutta. (Non-member.)

are not very serious." Actual calculations on "commercial filters" (as distinguished from the "ideal filters" considered by the Author) would give him an entirely different view-point. He could not generally neglect the small resistance component in coil element which added up to a large value in actual filter networks (consisting of several sections each with several coil elements) and also could not neglect the resistance components of paper and mica condensers (which were used for V.F. range as well as Carrier range upto 30 Kc/s). It was only in higher frequency ranges where air condensers were used that the resistance component of condenser element could be neglected. The Author would therefore appreciate that attenuation and characteristic impedance characteristics, sharpness of cut-off, etc., of "commercial filters" would be much different from those of "ideal filters" in which resistance components were neglected.

Under the section—"Characteristics of different types of Filters", the Author had omitted consideration of band-elimination filters although he mentioned it in the previous section. It was also to be noted that phase-shift and characteristic impedance, characteristics which were no less important than the attenuation characteristics had been entirely left out.

Under the section—"M-derived Filters and Composite Filters", the state of affairs was rather distressing. The phase-shift characteristics of *single* m-derived sections shown therein should have been given. Further, a short discussion of *double* m-type sections, *six-element* and *five-element* band-pass sections which were actually used in communication systems should have been enclosed. The subject of "Composite Filters" which were so much used in actual practice did not get more than two lines. An account of the formation of composite filter by prototype and single m-derived sections and m-derived half-sections with attenuation, phase-shift and impedance characteristics of the component sections as well as of the composite (whole) would have been full of interest to the readers.

Under the section—"Use of Filters in Thermionic Valve System", the Author mentioned a few applications in precision measurement, in oscillators and radio receivers. There could be many other better instances in radio and television systems. The "band-pass coupling" used between r.f. stages for efficient transmission of wide-band, the interstage network between penultimate and final audio stages as well as the output

network of the final audio stage of high power class "B" modulation systems were interesting examples of wave-filters in valve systems. He would like to refer the Author to a paper entitled "Final Stage Class B Modulation" by C.E. Strong of Standard Telephones & Cables Ltd., for this purpose. Applications of high class wide-band filters and band-pass couplings abounded both in television transmission and reception systems.

The section on "Filters in Carrier Current Telegraphy and Telephony" appeared to be rather incomplete. Carrier Current systems and multi-channel radio-'phone systems were the greatest users of electric wave-filters and should have received better treatment. The "channel band-pass filters" in the terminal equipment of Fig. 10 a (as manufactured by Standard Telephone & Cables) consisted of five-element and six-element sections, not discussed in the paper. Siemens & Halske's Carrier systems used "differential filters" as shown in Figs. 1 & 2 all throughout. This type had not been discussed.

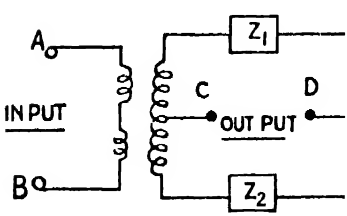


Fig. 1.—Illustrating Principle.

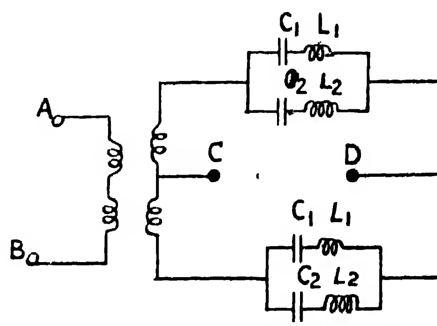


Fig. 2.—Illustrating Band-Pass Filter.

The section on "Crystal Wave-Filter" appeared to be meagre for such a highly developed subject. Low-pass, high-pass and band-pass types of crystal wave-filter had been developed and were in use in carrier and radio systems. Low-pass and high-pass crystal filters were used in "carrier broadcast systems" whereas band-pass type were used in "broadband carrier and radio systems". It would be of interest to know that band-pass crystal filters using crystals and condensers could give very little band-width and those with crystals, condensers and coils could give greater band-width sufficient for most purposes. Evolution of wide and ultra-wide band crystal band-pass filter had been of comparatively recent date (refer British Patent 5119/40 dated March 1940.)

In conclusion, he desired to congratulate Mr. S. N. Mukherjee for attempting to prepare an article on a highly developed subject like "Electric Wave Filter".

Author's Replies to Comments—(by letter)—Regarding Dr. Shiv Narayan's introductory remarks to his paper at the Annual General Meeting at Poona, he was very grateful to Dr. Shiv Narayan for his lucid exposition and he thanked him for the same. As regards his remarks about "the most practicable way of bringing about the relation LG-CR", he added that although the classical ideas of Heaviside in increasing the leakage G were well-known, the "inductive method of loading" certainly remained the most practicable method, as by increasing G, the attenuation of the circuit was increased at the same time.

Regarding Mr. S. P. Chakravarti's comments on his paper, he had gone through with great interest the comments made by Mr. Chakravarti. At the outset, he remarked that Mr. Chakravarti had failed to appreciate the essential purpose of his contributing a paper on Electric Wave Filters. It was never his intention to write an "up-to-date" review of developments and applications of electric wave filters. His idea was simply to arouse interest in the very important and growing subject, particularly for those who were comparative novices in the field of communication engineering. He had nowhere claimed that the paper was an original contribution, so that the paper was, of necessity, taken "entirely from works of well-known authors", as Mr. Chakravarti had characterised it. He did not think any useful purpose would be served by his answering in detail the various points raised by Mr. Chakravarti. His only reply to his remarks was as follows :—

"In introducing the subject to interested readers, I have selected a few broad aspects of the subject according to my own ideas. I have purposely avoided such intricate details as appeared to me not to fit in with an introductory treatment of the subject like "Electric Wave Filters" is entirely a matter of individual opinion, and what appears essential to one's mind may not be liked by another. I have also, in my own way, tried to be an earnest student of the subject and have certainly come across the topics discussed by Mr. Chakravarti. But I had no desire to write an "up-to-date treatise" on the subject, as would become necessary to include all the topics

mentioned by Mr. Chakravarti. I thank Mr. Chakravarti for his compliments, all the same."

In conclusion, he would invite Mr. Chakravarti to contribute a complete up-to-date review of the growing subject of electric wave-filters which, he was sure, would be highly appreciated by all those who were interested in the subject.

THE EDUCATION, TRAINING AND FUNCTIONS OF THE ENGINEER[1]

DISCUSSION[2]

Mr. P. C. Ray[3] ***(Bengal Centre.)***—In the absence of the Author of the paper, who was out of India, Mr. Ray introduced the paper to the members, and said that it was very illuminating and useful. With the growing industrialization in India, Engineers had come to occupy a very important position in life and therefore the grounding which an Engineer received at College was of prime importance both to the industries and to the Engineer himself. He therefore thought that the paper dealing with their training and education would provide a good food for those who were interested in the subject. He finally expressed his hope that members of the Institution would take part in the discussion of the paper so as to enable those interested to take the suggestions and opinions into consideration in formulating a scheme of education.

Mr. B. R. Kagal[4], in opening the discussion said that the tendency these days was to criticise defects in engineering and other systems of education. The primary, secondary and higher education were all open to criticism. He continued that the cause for unemployment was the wrong system of education and said that the Author had in his paper suggested that there were certain defects which could with advantage be prevented. The two tests, according to him, for determining whether the

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1. This paper by Lt.-Col. A. G. Warren, M.I.E., was published in the Journal, Vol. XXI—No. 1, April 1941, and has won the Viceroy's prize.

2. Discussion held at the Annual General Meeting on Sunday, 2nd February 1941, at Poona.

3. Superintending Engineer, S. W. Circle, Calcutta.

4. Land and Development Officer, New Delhi.

Note:—Lt.-Col. A. G. Warren regrets owing to War duties he has been unable to reply to these discussions.

education imparted to young students was useful or not, would be (1) whether Engineering Graduates coming out of a College got employment and (2) whether they satisfied the employers who had to select engineers for recruitment as regards their usefulness. Both these tests in practice would give an idea as to what the present system of education and training was like and whether any improvement was necessary. He added that he however did not think that the test of unemployment was a good test.

He would however consider the experience of countries like Europe and America in the matter. During the last 10 years they had waves of unemployment and slacks, but it was proved that unemployment in their cases was not solely due to system of education prevailing. The causes for unemployment were not necessarily defects in the educational system, but the deciding factor was the industrial and economical system. If the industrial and economic system worked smoothly there would not be unemployment whatever the system of education. The experiences of Public Service Commission and the various bodies who were out to select suitable candidates, who appeared before them, would make us sit up and take notice.

Mr. Kagal then went on to say that the different points that were discussed in the paper were very thought-provoking, but he could not help observing that they were controversial in some respects, all that, however, did not take away the interest which the paper had created amongst every member of the Institution.

On page 72, the Author said "The status of the Engineer is still a dubious one, at least it is so in India". That before this could come about, some re-adjustments were essential between the two classes of "economics of policy" and "economics of practice". The suggestions made by the Author indicated that he preferred the two to be merged ; that the Engineer who controlled the "economics of practice" should also be the Engineer who controlled the "economics of policy". There was some confusion to the extent that these two functions could not be controlled by the same Engineer at the same time. The Engineer who had controlled the "economics of practice" might control the "economics of policy" after some 3 or 4 years. He explained that practice must be guided by policy, otherwise there would be confusion. Of course there

were engineers who had risen from "economics of practice" to "economics of policy", but the higher administrative posts were likely to be for engineers who had studied "economics of policy."

The Author thought that the present system of education in India was only confined to the scientific aspect of instruction and that the administrative side was neglected. Mr. Kagal explained that the activities of the Institution of Engineers (India) had now been directed to remove that defect.

The Author had compared the Engineer in India with the Engineer in foreign countries and had referred to the position of the American Engineer and the higher responsibilities he occupied. According to Mr. Kagal the higher position and responsibilities that an American Engineer enjoyed was not due to the training but was due to the experience that he acquired and the efforts he put forward during his professional career. The Author had dealt with the various aspects, *viz.*, business engineering, comprising of book-keeping, accountancy, commercial and engineering laws, administrative, etc. He then referred to the omissions by the Author in the paper and advocated careful study during the progress of the educational curriculum and the method of indexing habits and keeping notes which, he said, should be encouraged and which alone according to him led to research. He said that the paper did not refer to the Research Section in Engineering and emphasised that this was very important in India. There should not be mere tendency to keep to tradition but to adapt the system to make it suitable and the training should enable the students to take an intelligent view of things.

Mr. Kagal further mentioned the two aspects of engineering referred to by the Author and said that the function must be more varied and recommended additions of two more functions to the list given by the Author on page 80, *viz.* (7) Recording and Indexing and (8) Research, to make the functions of an engineer more complete. On page 86 the Author had anticipated certain objections to his proposal of introducing the drastic changes and in the pages that followed he had given his replies thereto and had suggested that as an average engineer got practice, his every day work gave him less of the practical and more of administrative side. The problem therefore reduced itself to lessen the technical subjects, and replace them by a set of other subjects.

He then referred to page 91 where the Author had dealt with Co-operative Courses and explained the differences between the Sandwich system of England and Co-operative system of America.

Referring to the appendices, Mr. Kagal said that Appendix II was rather important, as the Author had classified various grades and faculties and given percentages and opined that it was again a matter of experience and therefore he invited suggestions from members on that point. The Author had under Appendix III given a kind of curriculum which he considered suitable and in that connection the speaker referred to the Educational Sub-Committee of the Institution and expressed a hope that guided by the able President, the ultimate result in the matter of revising the curriculum would be a success.

Dr. Shiv Narayan*[5] *(Bombay Centre).—Dr. Shiv Narayan said that the proper education of engineers in all branches of engineering was important because it was with that knowledge and education that graduates practised as engineers. The paper covered 35 pages including 5 appendices, the last of which was a list of 31 books on accountancy, banking, book-keeping, administration, organization, commercial and engineering laws, depreciation, estimating and writing of specifications. According to the Author those were "some works likely to be useful to engineering students" for the preliminary instruction, in which at least 36 hours should be devoted to administrative courses, of which 8 hours should be devoted to administration which was essential for all grades of officials in two types of engineering undertakings specified in Appendix II. 11 out of the 31 works of Appendix V related to this function of an enterprise or undertaking. This subject was therefore shown to be of sufficient importance to warrant its inclusion in an engineering syllabus and ought to find a place in it, where it did not do at present, as in the majority of Indian Engineering Institutes and Colleges. The technical function was also required of all grades of officials in engineering undertakings to a greater or lesser extent. Under this came estimating and writing of specifications which required 12 hours out of the total of 36, and 6 books out of the 31 mentioned above. Regarding the remaining subjects and functions, not required by some grades of officials at all, *vide* Appendix II, there was bound to be difference of opinion It seemed desirable that they should be reserved for study after a student had

5. Retd. I.E.S. Poona, Professor, Muslim University, Aligarh.

blossomed into an engineer and felt the need of one or more of them. It should however be stated that even existing courses of several engineering colleges included book-keeping and allied topics under the heading "Engineering Economics."

Dr. Shiv Narayan continued that one subject which the Author of the paper under discussion had not referred to but one which was of peculiar importance for Indian engineering students was that of writing reports and letters in correct, concise and telling English. Precis and technical essay-writing were included in the syllabus for the degree of Bachelor of Engineering of the University of Bombay, for each of the three branches of Civil, Mechanical and Electrical Engineering.

The suggestion of adding the above-mentioned subjects to those already included in the syllabus raised the question of the duration of the course. In most of the English Universities the Engineering course extended over 3 years, whereas in the vast majority of American Engineering Colleges and Institutions, the course extended to 4 years. In India, some colleges took 3 years to cover the course whilst others 4 years. It seemed desirable that in this matter as well as in the standard of admission and the time allotted to theoretical and practical instruction, there should be greater uniformity than what existed at present, at least among Indian Engineering Colleges affiliated to Universities recognised by the Government. The Institution of Engineers (India) ought to urge the Government of India to have this reform considered by the Indian Universities Conference and put into practice as far as feasible and as soon as possible.

The Co-operative system of America and the Sandwich system of England were not in vogue in India, except perhaps to some extent in the Punjab Engineering College which was situated close to the Moghalpura workshop of the N. W. Railway. In the absence of such a system, the introduction of which was not always feasible in a country like India where industrialization had not made the stride it had made in Western countries, it seemed essential to arrange for the students to spend a large part of the vacations and of the year preceding their employment as engineers in large workshops or power stations or installations.

In order that practical training in working industrial undertakings might be arranged for all engineering students, it was imperative that there should exist a large number of such undertakings willing or bound to admit students as apprentices.

For this purpose, the pace of industrialization (preferably under Indian control and management) should be accelerated with the sincere and substantial assistance of the local, provincial and central administrations. Till this happened, Indian students should be offered facilities for practical training in the big factories, etc., of the United Kingdom, Canada and other large countries of the Empire. The British Government could moreover come to an understanding with the U. S. A. regarding the admission of Indian students in the undertakings of American firms patronised by them, particularly those which had contracts for supply or construction with the Government of India, British Indian Provinces or the Indian States.

A fair measure of agreement should be forthcoming for the ideas, advocated by the Author in the conclusion of this paper. It was high time that engineers were registered in this country, and a General Engineering Council established, which would insist upon a high standard not merely of technical qualifications but also of professional probity. In a poor country like ours, the temptation to yield to corrupt practices or to accept unjustifiable offerings in cash or kind was naturally greater than in the richer lands of the West, and the tendency to rate private gain above public good to the extent of taking oneself what should go to the coffers of the State ought to be curbed by refusing to register engineers whose record was not quite clean and by dismissing members who had sullied their reputation and brought dishonour on the profession, in the same way as was done by the High Courts in the case of lawyers and by the General Medical Council in the case of doctors and by other important authorities in the case of their members or officials.

Last but not least, an engineering student should remain so, even after graduation from his college. The best engineer was one who was continuously studying the literature of his subject, reading and contributing papers to the Institutions and Journals of Engineers and combining the practice of his profession with thoughtful perusal of the literature dealing with it.

Mr. S. B. Joshi[6] pointed out some glaring defects in the engineering training and education. He laid stress on the necessity of co-ordination between different Universities and Institutions and strongly urged that the University should take

6. Engineer and Contractor, Bombay.

into consideration the suggestions and opinions of Institutions like ours while revising the syllabus, etc. They should consult us and in case they did not, we should approach them,

Mr. Khaja Azeemuddin[7] said that the Author had raised some very interesting questions in his paper, *viz.*, how much of the work involved in carrying through a large and important scheme was really technical and how far the college curriculum had been of help in this connection. The engineering Colleges had not attempted to turn out a finished product but to graduate men with capacity to become engineers. They had trained engineers in the rational solution of problems by building the engineering curricula upon a mathematical and scientific foundation. Mathematics, Science, Mechanics and the fundamentals of engineering were used to develop reasoning power and the ability to arrive at truth by observation and by experiment. The policy had been to give an important place to studies that developed in students the ability to understand and interpret correctly the ideas of others as well as the capacity for clear logical thinking and clarity of expression on their own part ; the specific information involved was of secondary importance. Even the purpose of practical examples should be mental training rather than mental storing. As instrumentalities for training they were of direct and permanent value ; as stored information they were ephemeral and futile. The engineering student was not a bottle to be filled with information or a sponge to soak in culture, he was a growing entity who must learn to find himself, learn how to attack a problem, to act promptly and correctly and also acquire some appreciation of what might be expected of the practising engineer.

No doubt, the college course studied by a young engineer even if above the average both in diversity and thoroughness, still could not train him specifically for a single one of the numerous problems he had to encounter. It however laid the foundation of all the variety of work by giving him the fundamental theories involved in the various problems that he would be called upon to solve. Once such theories were understood it was easy enough to apply them to a large number of different situations and problems and to effect the solution. It had been widely recognized that the few years spent in college could provide only a foundation for an engineering education and that this must be supplemented by years of

7. Executive Engineer, P.W.D., Hyderabad, Dn.

experience and study. Much of the specialized knowledge and technique of engineering must be acquired by the young engineer after graduation.

Mr. Azeemuddin continued that engineers who prospered in their kaleidoscopic situation were those with sufficient versatility and adaptability to shift with the times ; and these qualities were derived from proficiency in fundamentals that did not change. Professional success was so largely dependent upon the individual, the environment and the opportunity, that, outside of the fundamentals, other questions seemed to be of minor importance. Even assuming business administration as of major importance in the future career of an engineer, still in order to remove the obstacles to increasing the breadth of the engineering curricula, there must be improvements in the status of the courses and the effectiveness of such teaching in the average Engineering college.

Even in U. S. A. where this question had received the greatest consideration the result had been far from satisfactory as was evident from the following statement made only a few years ago by Mr. L. C. Marshall, former Director of Economics and Business at the University of Chicago :—"As matters stand to-day there is a lamentable weakness in the instruction staff of the collegiate schools of business administration. If a scholar from Mars were to make the rounds of nearly 200 colleges and Universities which alleged that they had teaching staff in business, he would find the general situation all but incredible."

After all how much could we expect to influence the career of an engineer, by means of a six or eight hour course in administration, commercial laws, banking or accounting, taken at the time when he was a student, when the time actually arrived after perhaps ten years after leaving college, that he was called upon to assume some managerial position ? Certainly not a great deal. If an engineer expected to become a valued adviser along lines other than technical, he would have to post himself on the problems of the day as other people do. A little more or less work in college would have little or no effect. It was almost universally recognized that bankers, politicians and corporation managers who have had some education, including a considerable proportion of economics and similar studies calculated to be a good preparation for their work, had not made quite as good a job at their business as had the Engineer. Let the Engineer thoroughly learn the

needed fundamentals of his own profession and he could prepare himself for whatever responsibilities might come in his way by study in the field that he was called upon to occupy.

Mr. Azeemuddin further added that the Author had only touched lightly on the subject of liberal arts. In his opinion, that was probably just as important a subject, if not more, as training in administrative business. If engineers were to be the leaders of industry, the engineering courses must be liberalized by the addition of such courses in liberal arts as would help the graduate engineer to meet men of culture on even terms. The need to-day was for the philosopher engineer or for the educated engineer who was familiar with the best literature in his own language and probably in that of one or two others ; also to read many branches of learning understandingly and to discuss them intelligently. The growing recognition of the desirability of a background of liberal and cultural studies for a professional man was now universally recognized. Whether this additional course could precede or follow the traditional engineering course was a moot question. There was a group of educators who believed that there was a certain fundamental information that all students should have before going into anything savouring of practical work. On the other hand there were others who maintained that the liberal studies should come later in the course, when the student was more matured, more thoughtful and more efficient.

The next important issue in the education of engineers was the training in research work. The world to-day was passing through an era of research. The field of engineering had now developed to such an extent and complexity as to give rise to a real need for additional scholastic training for a considerable number of engineering graduates of superior ability. Industry should recognize the value of advanced work and make it possible for the engineering student of a high order of ability to capitalize upon it. The speaker then suggested that the engineering Institutions be divided into two groups, the Schools of Technology and the Engineering Colleges. The Technological Schools should admit students after matriculation for a four years' course in which a great stress should be laid on teaching the fundamentals of engineering and allied practical examples together with a few courses in liberal arts and economics to keep the interests of the students alive. Such schools would train men for the lower grade of engineers that were generally required in a large number. From these

schools-only those who showed an aptitute for their work and promise for the future should be taken in the Engineering College, where they would receive a thorough grounding in engineering research and in any specialized work that they would like to take up that a particular industry might demand. If such an Engineering College was to be a success, it would have to be an All-India Institution, so that it might possess sufficient resources to train leaders of men and industry.

The speaker then quoted the instance of Cooper's Hill College of Engineering which was in existence some years ago in England. That Institution had available to it all the resources of the government and the engineers who graduated from it had all been without exception, men of sterling qualities and world-wide fame. The reason for this was that due to the lucrative salaries that were offered, the best professors that England could command were rendering their services in that College. The All-India Engineering College mentioned above should have similar attraction to gather experts from all over the world in order to infuse into the students the best that they could give and it should possess laboratories of a high order of efficiency and facilities for practical training. It should also have the co-ordination of industry and government for recruitment in their higher services of students who came out successful.

Mr. Hasan Latif[8] stated that the object of the paper was really to stress the necessity for business training. He said that in Hyderabad (Deccan) they had a test for the business training along with engineering courses right from the inception of the Engineering College to turn out more complete business engineering students, and that the course included over and above engineering subjects, subjects like accountancy, commercial law, economics, etc., and that with his 32 years of experience he was in a position to say that these were useful subjects.

He further thought that the Author had in his paper left out a very important thing and that was the physical development of students. He stressed the necessity for physical development for engineers and said that it was very essential that engineers should be strong in physique so as to bear all the vagaries of weather and climate and to do hard and strenuous work. To him physical development was more important than technical training, which he thought was just a matter of routine.

8. Principal, Engineering College, Hyderabad, Deccan.

He felt that too much time was taken in imparting primary knowledge about engineering in too many subjects, which he thought was not useful. He stressed on the necessity of experience of practical subjects. In Hyderabad they taught allied subjects, like chemistry, to a Civil Engineering student, and stressed that expert work on a particular line only should be encouraged, and that it was of no use to overfill the brains of all students with knowledge which did not come of use to them. Specialization according to him was very necessary.

In conclusion he referred, with a heavy heart, about professional manners, which should also come to occupy a place in the training of students, so that the experiences one came across due to lack of these manners could be averted. He cited instances from his experience to show what professional manners meant and the result of the lack of them.

Mr. E. K. Ramaswamy[9] narrated his own experience in the matter of giving business engineering training to engineering students and said that in Bangalore they had started giving training in economics, etc. He then explained that they gave training in ordinary economics to the First Year Engineering students and then engineering economics.

He then continued that in England by way of a general course, a knowledge of Tropical Diseases was also imparted with a view to protect the workmen and labourers against tropical diseases, etc. He also referred to other subjects which were not included in the present day curriculum of studies and said that Sanitary Engineering should include subjects of Chemistry which was necessary and Mechanical Engineering, subjects like ammunition manufacture, etc. He referred to the visit of the members of the Institution to the Ammunition Factory at Kirkee and said that students should be taught how to design such factories. All these subjects, he said, were included in the curriculum of the Bangalore Engineering College.

He then made a reference to the Co-operative method or Co-operative course used extensively in America and Europe and said that conditions differed in India from those prevailing in America and Europe and that they were useful there because the colleges were situated near the workshops and industrial undertakings. In this connection he threw some light on the efforts Mysore Government were making in the matter of

9. Principal, College of Engineering, Bangalore.

giving practical engineering training to their students. Machinery tools industry, iron works, etc., were, he said, to be started under the patronage of the Mysore Government and the facilities of practical training would then be extended to their students. Under the above circumstances only the co-operative system would be possible and useful. He said that co-operative system lengthened time and instead of 4 years' course, 6 years' course would be required. In India half the time of a man's life was spent in acquiring and trying to gain knowledge and the other half in looking out for employment, and therefore he did not believe that the co-operative system was suitable to Indian conditions.

He then narrated his experience about the facilities for practical training and said that they were really disappointing. Only a few Institutions took interest in engineering graduates and cited an instance of a Workshop Superintendent whom he knew, who would not allow responsible work to be attended to by the engineering students, as, if something went wrong, he would be responsible for it and not the student.

He laid stress on the necessity of utilising vacations in acquiring practical training in a very extensive way and not to waste their time by idling away. He therefore suggested that the three months' vacation should be cut down to two months and in that time the students should acquire practical experience and training to be of use both to themselves and industries.

Ag. Principal Taraporewala[10] congratulated the Author in bringing out such an interesting paper and said that the paper and the discussions thereon gave some idea as to what was wrong with the training of our young engineers. All colleges expected too many things from their students, with the result that they were disappointed in their expectations. It was absolutely important that we should get the best out of the students and that was not possible unless they got practical experience and training. He referred to the other aspect of the subject and said that there was something wrong in the system of imparting knowledge. The colleges had confused training with information. It was not the information that counted. They must however know how to extract work from their students and try to pump out information rather than pump information in. He then described what he meant by his statement and explained that by merely mentioning a

10. College of Engineering, Poona.

subject in their lectures, the professors should ask their students to find out and learn for themselves from books, from libraries and other sources and then guide them properly in the subject. He was however constrained to observe that here in India it was physically impossible to attain that standard, as the professors had to deal with a large number of students in their daily life and said that they had no facilities to do so.

Mr. K. L. Jain[11] also took part in the discussion.

The President, (Mr. N. V. Modak) requested the Hon. Secretary to convey the thanks of the Institution to the Author of the paper and said that the subject was of great importance and that he was pleased with the discussion that had taken place at the meeting.

He then gave his personal opinion about the subject. 80 per cent of the Engineer's work required general knowledge and routine and 20 per cent required technical knowledge and training. He said that we could not afford to waste money on our children, as the present day Engineering course was a lengthy course requiring a candidate to pass his Matriculation, then Inter Science and then an Engineering course of 4 to 5 years. Natural aptitude was very essential in taking into consideration whether a candidate could be made a useful hand in the general organization ; we should therefore try to train up for some years engineering students with natural aptitude from the 4th standard and then send them to engineering colleges and there they should be trained up in an engineering atmosphere. He deplored the fact that in the absence of the above-mentioned facility, we were not so successful. As regards specialization, he thought that it should be left to a post-graduate course.

Prof. A. Viswanath[12] (by letter).—He thanked the Author for having brought to the forefront the supreme need for greater appreciation and recognition of the work of the Engineering profession as of vital importance in nation building and for formulating schemes to improve the training and status of the Engineer so as to keep pace with the dynamic changes that were taking place in industry and commerce. When it was noticed that in India, a student had to spend 6 to 7 years of study after Matriculation to secure a University Degree in Engineering, whereas in foreign Universities, a

11. Ordnance Mech. Engineer, Deolali, Bombay Presidency.

12. Professor, College of Engineering, Madras.

similar Degree required only about half the number of years after Matriculation, there could be little reason as to why the scope of Engineering education could not be enlarged so as to include Business Administration in all its aspects without lowering the standard of technical attainments.

But the main impetus for such an enlarged study and training must come from the status assigned to the engineering profession. If it was recognized that the Engineer's contribution was essential for nation building activities, that recognition must find expression in the status assigned to him. Unfortunately however, the Engineer's status was ranked inferior even in Government circles to purely administrative offices, and Engineering Departments like P.W.D., Industries, Agriculture, etc., were often headed by a purely administrative officer. The examples set by some of the advanced states like Mysore and the Indian Railways were however a welcome contrast and served to show how engineers could as well be highly efficient administrators.

Closely allied and inseparable from the status were the prospects and emoluments of the profession. These were the forces that guided parents and students in choosing a profession. It could not be denied that in India the status and emoluments of the engineering profession were ridiculously out of proportion to the long period and expense involved in their training and education compared with other professions of equal nation building importance, which involved far less time and expense and carried higher prospects and status. The best brains of the country were therefore not sufficiently attracted to this essential profession, but were diverted to cream professions like the I.C.S., Finance, Commerce, etc.

It was no wonder then to see that while India had produced a good many eminent lawyers, businessmen, financial experts, politicians and administrators, etc., the number of eminent engineers was very small.

The remedy for these was obviously to devise measures that would attract a fair proportion of the best brains of the country to this profession and this would involve improving the status and prospects of the profession. For effecting these and all connected improvements in the science and profession of Engineering, he welcomed the idea of a General Engineering Council as proposed by the Author.

Mr. F. Sims[13] (by letter).—The Author had put forward many thought-provoking views in the course of a most comprehensive paper but had omitted any reference to what, in his opinion, was a matter of fundamental importance. This was with regard to the initial education both general and technical of the engineer-to-be. It was an adverse handicap of the first magnitude for a boy to be obliged to learn and master a foreign language before he could hope to achieve the essential higher general or technical education necessary for his future career. This state of affairs was a serious reflection against those responsible for the system in the initial stages. Had India been a land such as Central Africa or Borneo there might have been some excuse for such an inauguration. In Japan, a country which had made phenomenal progress in industrial and engineering development, Government made sure that all necessary text books were translated into the language of the country thus enabling the people to be educated on progressive lines with their mother tongue as the medium of instruction.

By confining the medium of instruction to a foreign language the number of those able to benefit by such instruction was necessarily very limited and many with inherited engineering instinct and skill were debarred from taking their proper place in their country's development.

A point well raised by the Author was the necessity for the systematic practical training of the student. It was unfortunate that there were relatively speaking, so few places where adequate practical training could be obtained and it was regrettable to find so many young men with high academic and technical qualifications who had little or no idea of any practical application of their theories. The remedy for this state of affairs was with the the authorities concerned who should make it their business to see that their trainees were given complete instruction for the profession they were to practise and not turn them out as a half finished product to sink or swim as best they could in a fiercely competitive world. Such a condition was just neither to the student nor to employers and least of all to this country of unlimited possibilities.

He further added that the Author had rightly stated that the Engineer of to-day was required to have an increasingly wider knowledge of co-related subjects but would it not be

13. Electrical Inspector, Bihar Government, Patna.

unwise to place the teaching of these subjects as concurrent with the regular technical course. It was better that these subjects could be given in post graduate courses when more closely detailed attention could be given to them.

Hyderabad Centre[1]

Mr. C. E. Preston [2] congratulated Col. Warren for his valuable paper and added that his analysis in Appendix II of the 6 functions to be fulfilled by Engineering personnel in 2 types of undertakings was most interesting.

He favoured giving commercial and administrative training to engineering students for an hour weekly throughout the 3 years' degree course in Engineering, but did not agree with the Author to cut short the designing portion of studies as these principles were essential to the Engineering students.

Mr. Preston approved the "Co-operative system" of training and referred to the Loughborough College scheme, which nearly approached this system. He however contented there were difficulties in this country to introduce co-operative system as most of the engineering undertakings were Public service ones and very few manufacturing companies. He would therefore recommend the College apprenticeship course for engineering graduates similar to British practices or vacation courses which might with advantage be introduced.

Mr. Lokendra Bahadur [3] considered the paper valuable for improving the Engineering Education in general and the scope and functions connected therewith. He hoped there would be an expansion of industrial and commercial functions and to attain that end he would recommend examination of the engineering syllabus with special reference to the Osmania University by a competent committee which could decide the period to be allotted to extra subjects recommended by the Author. The Co-operative system was also worth considering.

He attached importance to the status and functions of an Engineer and to stop the unqualified practioners, until a General Engineering Council was set up, he recommended the P.W. Department to take up the question. He further

1. Discussion at the Hyderabad Centre Meeting held on 16-8-41.
2. Principal, Osmania Technical College, Hyderabad Deccan.
3. Executive Engineer, Raichur, Hyderabad Deccan.

favoured technical men occupying the administrative posts and that passed engineers and subordinates should be preferred to simple graduates in the appointments as Tahsildars, Surveyors, Land Recorders and Girdawers, etc., and recommended the House for appropriate action in the matter.

Mr. K. V. Rao[4] congratulated the Author for his useful paper and agreed with the suggestion that an engineer should be conversant with the legal aspects of his responsibilities. He however did not agree with the Author that it was possible to compare the relative capabilities of different individuals by figures given in Appendix III. He opposed the charge against the teaching staff that they were slave to their own course and magnified their importance. On the other hand he found fault with the P.W. Department as these departments offered little scope to young engineers to use their initiative.

He then referred to the Author's remarks, that part of the syllabus in the engineering course was never likely to be called upon to put into practice and remarked that most of the young engineers were poor in practical application of their college training and therefore emphasized on the study of fundamental principles thoroughly. Referring to page 90, he added that "Estimating and Writing of Specifications" was being taught at present and suggested these subjects should be taught during the period of apprenticeship rather than during the normal College course. Further he favoured contracts should be given to engineers instead of unqualified persons and that this would also partly solve the problem of unemployment.

Mr. L. Gangadhar[5] stated that the aim of science was "to maintain and to improve" without which no industry could improve, and the acknowledged superiority of some nations could be traced to their better scientific researches. India had no large scale industries and the existing curricula in the Engineering colleges were framed to meet the requirements of P. W. Department. Times had changed and it was essential now to have specialized courses and queried if it was advisable to tax the students with commercial subjects recommended by the Author. He then referred to a circular letter issued to the practicing engineers in U. S. A. regarding the characteristics most essential for success in engineering. The result of

4. Hyderabad, Deccan.

5. Sub-Engineer, P.W.D., Hyderabad Deccan.

that enquiry showed that in the opinion of 7,000 engineers who replied, such personal attributes as character, integrity, responsibility, initiative judgment, commonsense, efficiency, and thoroughness made up 75 per cent in determining the success of an engineer while knowledge of the subject and technique of practice and business formed the remaining 25 per cent. He then referred to the training scheme of the Cincinnati University (U. S. A.) and considered such an arrangement useful for India.

PAPERS MEETINGS

Bombay Centre

Technical Education

A General meeting of the Institution of Engineers (India), Bombay Centre, was held on Thursday, 31st July 1941, at 6-15 p.m. (S. T.) in the Institution Room when Mr. P. P. Adalja, M.I.E., initiated the discussion on "Technical Education."

40 members and 10 guests were present.

The Chairman, Mr. P. E. Golvala, informed the members that henceforth it was decided to have such men as were directly interested in the subject matter of the lecture as Chairmen of the lecture meetings. He proposed Mr. N. V. Modak to the Chair.

Mr. P. P. Adalja [1] in opening the discussion traced the bright historical background of the advancement of Technical Science in India and narrated how the present day Technical Education in India was only meant for supplying lower subordinates and was never intended to further the needs of a country bent upon industrialization to such a scale as to be able to convert its own raw materials into finished products within the country, so as to increase the national wealth.

The lecturer emphasized how in the present circumstances of India it would require great sacrifice on the part of her youth to bring the country to her former glory. He then lucidly

1. Engineer—Architect, Bombay.

explained how technical operations were controlled and executed and formed a beginning of Technical Education to the child. He further explained how the child could be given a technical bias in the Montessorie system by developing his powers of observation. Education imparted during childhood had a great bearing on the future of the child. He then pointed out how the children could grasp greater details during schooldays, if given proper facilities in and out of school and instanced the Deutche Museum at Munich as an ideal.

Turning to the College education Mr. Adalja specifically recommended that the standard of entrance should be that of Matriculation and that the first three years should be covered by a Diploma course and the selected few Diploma-holders should undergo a further training of two years to get the Degree. In fact he wanted to introduce Technical Education in the pre-Matriculation stage and wanted a separate Matriculation (Technical) examination. He then narrated the reasons why the College graduates after receiving such high education had to face unemployment. The obvious solution was extensive national development of small and heavy industries. He then explained the difficulties of being required to learn a foreign language and advocated the introduction of a national language. He made it clear that India could not afford to ignore development of agriculture and irrigation scientifically.

The lecturer emphasized the need for training in mechanized and aerial defence and deplored the present state of affairs in India.

He advocated that practical training should be given to our students and that education should be made very cheap. He further stressed the necessity of co-ordination of efforts between different bodies and advocated the establishment of a Central National Institution. He concluded by a general appeal to all to unite and strive towards that common goal.

Mr. K. N. Lilaoowala[2] stressed the need of specialized training in Production, Commerce, Sales, Works management and gave instances of such special facilities on the continent. He wanted industrial concerns to spend something on Research.

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2. Electrical Engineer, Moon Mills, Bombay.

Mr. C. H. Shah [3] advocated the system of honorary lecturership in the Colleges. He bitterly complained against the attitude of most of the employers whose short-sightedness and greed simply worked to kill all initiative in their employees.

Mr. M. N. Kulkarni [4] suggested that the employers will only learn to give proper value to their employees if the latter refused to be contented with the wages of a mere workman and prepared themselves to stand on their own legs by making a small beginning. He gave instances of how illiterate people were showing great initiative and were earning more than their educated brethren. He thought it was not difficult for our trained men to follow their example.

Mr. K. T. Divecha [5] agreed that the Technical Education began with the childhood but he cautioned members against very ambitious ideas of cinema films, expensive toys, etc., which poor India could hardly afford. He thought there was nothing wrong in the actual education that was imparted in the Colleges. What was lacking was the general aptitude for Engineering education during the school days. He advocated co-operation between Government and the Municipalities for affording facilities towards this end. He had no doubt that we would get good mechanical and electrical Engineers when they got proper opportunities.

Mr. V. R. Vaidya [6] did not approve of the present method of appointing inexperienced men as teachers in Mechanical and Electrical Engineering merely on the strength of their academic career. He also advocated greater emphasis in the colleges to the aspect of manufacture.

Mr. R. K. Nariman [7] narrated the story of Napoleon who said that the child's training began with the mother. He complained against limited facilities for Technical Education whereby a large number of intending students had to be turned out. He pointedly drew attention to the fact that the Engineers could not afford to ignore civic duties and must enter municipalities, legislatures, assemblies, etc.

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3. Structural Engineer, Garlick & Co., Bombay.
4. (Non Member).
5. Engineer, Senior Partner, Sykes, Patkar & Divecha.
6. Asst. Engineer, Tata Hydro-Electric. Power Supply Co. Ltd., Bombay.
7. Hon. Secretary, Institution of Engineers (India).

Mr. K. V. Kini [8] advocated that the control of the Government on Engineering Colleges should be removed. He was in favour of the standard of admission to be kept as high as Inter-Science. He complained against the over-emphasis given to some subjects like Geology in the Engineering Course.

Mr. H. D. Henman [9] was of opinion that the students must come out of the Colleges at an early age. He wanted students not to worry about emoluments during the first years during which time they should try to learn as many things as possible.

Mr. S. B. Joshi [10] said that when the British came into India, the learned class of people, who were working as priests or pleaders learned English and took to Engineering. The proper person who had a hereditary aptitude for Engineering has not come to the top due to illiteracy. He advocated that the emphasis given to linguistic tendencies during school days should be shifted to technical work. He explained how the present Matriculation standard in Bombay was in par with the standard of Matriculation in other countries and opined that it was necessary to bring the standard of entrance to that of Matriculation, if the boy was to come out of college for field experience at an early age as rightly pointed out by Mr. Henman. He advocated that greater and greater knowledge of Geology was necessary for Engineers in the present circumstances of India, when many of her resources were untapped.

The Chairman : (Mr. Modak) in winding up the discussion explained how it was a great problem to eliminate misfits and bring in students with a natural aptitude for Engineering. He further explained how marks in examinations could not be a proper criterion for such selections.

He thought that the best way was to establish an ideal Institution where all our ideas could be brought into function and their results demonstrated. He agreed that vocational bias should be given at an early age of fourteen so that the students would be artisans, foremen or engineers according to their means and other capacities. In his opinion the city of Bombay was the right place for an Engineering College. He

8. Consulting Civil Engineer, Bombay.

9. Controller of Stores, B. B. & C. I. Rly., Bombay.

10. Engineer & Contractor, Bombay.

emphasized the need of co-operation and deplored the waste of time and money caused by duplication. He commended the efforts of the Government of India in this direction and had full trust that the Institution would co-operate with them.

Road Deterioration in India*

Mr. P. E. Golvala in the Chair

Mr. T. R. S. Kynnersley in initiating the discussion said that the provision of good roads was a vital necessity to any civilized country and its importance to India could not be too strongly emphasized. He said that the three main causes of deterioration of roads in India were (1) growth of transport, (2) lack of maintenance at the correct time and (3) unsuitability for the nature of traffic.

Continuing Mr. Kynnersley said that the main trunk roads in India were designed on the old principles of Macadam. This type was suitable for the old type of transport such as the slow moving bullock cart. But it could not stand the combination of the steel tyred bullock cart and the fast moving motor traffic. The steel tyre of the bullock cart crushed the road surfaces and the fast moving buses picked up and threw back this crushed material. He then explained by sketches how the repetition of this process resulted in formation of pot holes which were not infrequently 17 inches. Growth of transport could not be stopped and the remedy for the damage done to the roads must be sought elsewhere. Damage done to the road by the steel tyre of the bullock cart could be prevented by the use of pneumatic tyres. Use of such tyres for the bullock carts was advantageous both to the carts as well as to the roads. But he did not propose to discuss this controversial point in detail.

The second cause of the deterioration was lack of maintenance at the correct time. This was due to (a) lack of funds, (b) lack of method and (c) wrong method. As regards funds he gave instance of America which greatly improved its road system in a short time by issue of "Road Bonds." Real difficulty in raising loans for road development was that the road being intangible asset the advantage consequent upon the improvement and the development of roads did not accrue

*A discussion initiated by Mr. T. R. S. Kynnersley M.I.E., of Concrete Association of India at a General Meeting held on 13th August, 1941. Attendance 46.

directly to the source from which the money came. Otherwise there was no disputing the point that good roads resulted in direct profit to those who used them. He showed, by means of a comparative chart, how the expenditure on roads in India did not increase proportionately to the increase in Government revenue from petrol, import duty on vehicles, etc.

Coming to the other factors which contributed to lack of maintenance at the correct time he explained that by lack of method he meant lack of technical knowledge regarding roads amongst the Engineers in charge of roads. He thought it was necessary to have a special branch for "Roads" in the P.W.D. and the District Local Boards. As regards the proper method he explained clearly that there was no such thing as the best road for any kind of traffic. It all depended upon the purpose for which the road was to be used. An Engineer's job was to suit the road to the traffic it was expected to carry for many years.

He then explained how the traffic was always naturally inclined to use a good road so that as soon as one was made traffic automatically came upon it. He emphasized the fact that experience in addition to theoretical knowledge was necessary for a road Engineer. As regards experimental work he said that a lot of research work was being done in America and the importance of having many road research stations in India could not be too strongly stressed. Mr. Kynnersley concluded his talk after explaining the experiments that were carried out on the Great North Trunk Road in the Province of Madras, where 46 different types of road surfaces were being tried. He gave comparative figures of road mileage in British India in 1927 and 1938.

Mr. W. B. Burford [1] enquired about the use of plastics for roads. He also wanted some information about the Test Tracks at Alipore. He enquired if figures were available of expenditure on roads in the province of Bombay as compared to other provinces.

Dr. Shiv Narayan [2] enquired whether wooden block pavement was being tried in the Madras experiment.

Mr. A. N. Patel [3] stressed the advisability of co-operative system for the development of rural roads. The villagers

1. Divisional Engineer, G. I. P. Rly., Bombay.
2. Professor, Muslim University, Aligarh.
3. Asst. Engineer, Bombay Municipality.

were idle for three months in a year and their labour combined with the technical knowledge of the Engineers could be utilized for road improvement and development.

Mr. S. B. Joshi [4] thought that the mileage of roads in India was very small (Mr. Kynnersley corroborated this by giving actual figures of road mileages in different countries per million of population). He thought that in view of the shortage of funds, great attention on the planning of roads was very necessary so that the maximum advantage with the minimum length of road could be gained. Classification of roads according to the kind of traffic expected on them was necessary. It would then be possible to restrict some roads for fast moving buses and bullock carts with pneumatic tyres and reserving the feeders for the steel tyred bullock carts. As regards technique of roads he thought that the average Assistant Engineer did not receive sufficient encouragement from higher officers to take greater interest in the technique of roads. He thought there was some fallacy in claiming a major part of the revenue from petrol, etc. for roads. Lastly he wanted to emphasize the importance of drainage of sub-grade as well as the surface for a good road and explained how any expenditure on improving a road would amount to a waste if no attention was paid to drainage.

COMPARISON OF ROAD MILEAGE IN BRITISH INDIA ON 1st APRIL 1927 AND 1st APRIL 1938.

PROVINCES.	1st April 1927. Metalled.	Unmetalled.	Total.	1st April 1938. Metalled.	Unmetalled.	Total.
Madras ...	21,440	3,290	24,730	21,441	14,276	35,717
Bombay ..	8,730	8,940	17,670	11,134	8,437	19,571
Bengal ...	3,400	16,020	19,420	3,887	87,305	91,192
United Provinces ...	7,710	27,670	35,380	8,200	23,389	31,589
Punjab ...	3,000	19,940	22,940	4,378	20,764	25,142
Bihar } ...	3,750	25,580	29,330	4,016	31,144	35,160
Orissa }				2,003	2,772	4,775
Central Provinces ...	4,670	3,770	8,440	5,469	3,193	8,662
Assam ...	560	8,810	9,370	692	10,379	11,071
N.-W. F. Province }				1,007	2,844	3,921
and Centrally administered areas }	2,550	4,750	7,300	1,510	5,301	6,811
Sind ...	100	12,350	12,450	362	11,439	11,702
British India ...	55,910	131,120	187,030	64,070	221,243	285,313

4. Engineer and Contractor, Bombay.

Mr. N. V. Modak [5] explained the difference between the roads in a city like Bombay and elsewhere. In Bombay the Engineer was more or less directly responsible to the public opinion which would never spare him as soon as anything went wrong. That was not the case with rural roads. The method of financing roads in Bombay was also different from that of elsewhere. He then explained how road census could not be taken as the sole guide in that, the traffic even preferred to take a long detour to avoid a bad road. He thought that a complete change in the Government policy was needed to improve the conditions of roads in India.

In reply to the discussion, Mr. Kynnersley explained the Test Track at Alipore and gave the figures of expenditure on roads in different provinces which were: Madras 112 lakhs ; Bombay 85 lakhs ; Bengal 96·2 lakhs ; U. P. 69 lakhs ; the Punjab 75 lakhs ; Behar and Orissa 16 lakhs ; Central Provinces 34 lakhs ; Assam 21 lakhs ; N. W. F. Province 23 lakhs and Sind 17 lakhs. He explained that wooden pavements for road were not practicable in India as monsoon conditions tended to lift the wooden blocks by effect of buoyancy. He agreed that a lot could be done by co-operative effort. He thought it was no use criticizing the present system of administration of roads unless suitable alternatives were suggested. He agreed that greater incentive for the Assistant Engineer was necessary, and did not see any fallacy in the chart shown by him as he never claimed the whole of the revenue from petrol, etc., for roads. His only grievance was, why the expenditure on roads did not keep pace with the increase in income. There was no doubt that proper drainage was necessary to keep a road in good condition.

Some Wonderful New Numbers*

Mr. P. E. Golvala in the Chair

Mr. D. R. Kaprekar at the outset explained some cuts in arithmetical calculations. Any number, he said, whose first digit was five could be squared by first writing the product of the digit in the tens place with its higher consecutive number and then writing $5 \times 5 = 25$ to the right of this higher consecutive

5. The President of the Institution of Engineers (India).

* A talk lead by Mr. D. R. Kaprekar on his researches, at a General Meeting held on 1st September, 1941. Attendance 39.

product. Thus $(95)^2$ is written by first finding $9 \times (9+1) = 90$, so that the required square is 9025. (Illustrations $(45)^2 = 2025$; $(125)^2 = 15625$; $(99995)^2 = 9999000025$). This method can also be applied to the product of two numbers of two digits sum of whose first digits was ten and which had a common tens digit. Thus $37 \times 33 = 1221$; $92 \times 98 = 9016$; $993 \times 997 = 990021$. This method could be extended to the product of two numbers ending in 75 and 25 respectively—other digits being common to both numbers. This could be done by writing 1875 after the higher consecutive product of the number to the left of 75 or 25. Thus $775 \times 725 = 561875$; $9975 \times 9925 = 99001875$.

The lecturer then gave an interesting method of checking if a number was divisible by 37. He said "Take any number say 210435238116 ; separate these digits by putting a plus sign after every third digit from right to left. Thus 210 + 435 + 238 + 116. If the sum consists of the same digits repeated three times, say 111,222,888, etc.; or more generally if the sum was divisible by 37, then the original number was also divisible by 37. (Illustrations—9620 would be separated thus 9 + 620 = 629. 629 was divisible by 37 so 9620 would also be divisible by 37 ; 2775 would be separated thus —2+775=777. The digit seven was repeated three times—therefore the original number was also divisible by 37.

These were a few of the numerous cuts in calculations discovered by the lecturer. He then explained briefly some elementary ideas of his discovery of 'Demlo' numbers.

A Demlo number consisted of three parts when the digits were taken in order from left to right. First part was called 'M' and the last part 'P'; M+P=one and the same digit repeated some number of times in the central part of the number. The number was symbolically written as M (v) P. Thus 87666579= 087 (6)* 3579. Numbers of the type of 123454321 were termed wonder "Demlo" numbers. He then explained some of the peculiar properties of wonder "Demlo" numbers. Multiplying a number by 162 resulted only in inserting as many nines between 1 and 6 and as many zeros between 6 and 2 as there were digits in the M or the P part of the wonder Demlo number. Thus $123454321 \times 162 = 19999600002$. Similar results could be obtained by any one of the following numbers :—

108—117—126—135—144—153—162—207—216—
225—234—243—009—018—027—036—045—054—
063—072—081

He then gave some very interesting properties of the squares and cubes of "Demlo" numbers, relation of "Demlo" numbers with recurring decimals, etc. He concluded his lecture by suggesting to those interested to read his articles published in the University and Mathematical Journals for a detailed study of "Demlo" numbers.

Mr. F. E. Bharucha[2] advised the lecturer to pursue his research by going to foreign countries and expressed his confidence that the necessary help would be given by some charities.

Acoustics*

Dr. H. J. Taylor, M.Sc., PH. D. (Lon.) Professor of Physics, Wilson College, Bombay, in the Chair.

Mr. J. P. Cassad[3] in opening the lecture said "The control of sound is everyday becoming increasingly imperative to human health, comfort and efficiency. Wherever groups of people gather indoors for entertainment, worship or education the problem of room acoustics or hearing conditions nearly always arises. In places where people work, study or eat, the need for quieting sound is urgent. This is even more true in hospitals and sanatoria. The problem in other places, such as in machine rooms becomes one of sound isolation, the control of sound transmission and vibration. For many years Research Workers laboured in the solution of these sound control problems. In the long list of Research Workers, Prof. Wallace C. Sabine of Harvard University is regarded as the pioneer in quantitative reverberation experiments. Upon the research of Prof. Sabine is based the science of constructive and corrective Acoustics as applied to auditoriums and public buildings and also to noise reduction principles used in quieting offices, banks and hospitals. It was Prof. Sabine who discovered that poor hearing conditions resulted from reverberation, the persistence of sound after its source had ceased. He attributed this phenomenon to excessive sound reflections from walls and ceilings. These reverberations prevented a listener from distinguishing successive words or sounds as definite and separate elements. The result to the listener, was irritation, confusion and consequent lack of intelligibility. Excessive

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2. Consulting Industrial Engineer, Bombay.

*A lecture given by Mr. J. P. Cassad, A. M. I. E. at a General Meeting held on the 11th September, 1941. Attendance 51.

3. Consulting Engineer, Bombay.

sound reflections were also responsible for much of the din which prevailed in offices, factories and other places where machinery was used. It was found that through the use of certain materials, the sound waves could be satisfactorily absorbed and excessive reflections eliminated. As a result of continued researches, many techniques and materials had been developed ; these served as a basis for the many systems of sound control through which many acoustical difficulties had been overcome.

The practical applications of most sound control principles were based upon the researches of Prof. Sabine who reduced the subject of sound as it related to building interiors to an exact science. He expressed the duration of reverberation under various conditions by a simple formula, $T = \frac{0{\cdot}05v}{as}$ where T = the reverberation in seconds ; v represented the Volume of the interior; a was the average co-efficient of absorption of all surfaces allowing for the relative areas of each type of surface and s the total surface in square feet. An absorption unit was theoretically based upon the area of an open window one foot square from which no sound was reflected. By comparison with that unit, the co-efficient of all acoustical and sound absorbing materials was measured. In all building interiors, there was a definite relation between the volume and the number of absorption units necessary to reduce reverberation to an optimum time. These data enabled the competent acoustical engineer to calculate in advance of construction, the acoustical or hearing qualities of an auditorium. In a similar manner existing buildings could be accurately analysed. All that was required for an acoustic analysis was a plan and section of the buildings, together with details of interior surfaces, furnishings and size of audience. Questions relating to echoes could also be investigated and commented upon.

A rectangular auditorium whose height was about one-third of its length and one-half of its width was usually found to be good acoustically. As the focussing of sound was associated with large curved smooth surfaces such as a dome or barrel-vaulted ceiling these were to be avoided from an acoustic point of view. In general, all circle and semi-circles both in plan and section should preferably be avoided. It was very desirable to limit the volume of an auditorium. As a rule, the ceiling height of an auditorium should be so adjusted that the volume of the hall in cubic feet should be based on a basic figure of 125 cu.ft.

per person for speech requirements and 150 cu.ft. per person for musical requirements as with this volume the natural absorption of sound by the audience was sufficient to bring the reverberation to a desired value. Speech and music demanded very exacting acoustical requirements upon assembly halls, theatres and churches. The spoken syllables and words must be distinctly separate to ensure intelligibility and ease of hearing. On the other hand a certain amount of tone blending was desirable in music. If a hall was used for both, the most satisfactory acoustical balance must be struck."

Coming to the question of acoustic materials, the lecturer stressed the fact that sound absorbing efficiency of acoustic materials depended on their porosity or compressibility or flexibility or in some cases to a combination of all three. The nature of the material did not matter at all, though when selecting an acoustic material, qualifications of its appearance, its fire-resisting qualities together with its ability to withstand the ravages of white ants in the tropics, its adaptibility in the design and conception of the building and its cost had all to be taken into account.

The importance of noise reduction in the offices, banks, schools, hospitals and factories was also stressed. In those instances it was the absorption on unwanted noise that was most desirable. The records of many companies indicated an increase in efficiency and a reduction in errors of clerical workers when located in quiet offices. Creative workers, executives and others whose duties required the exercise of keen discrimination were effected by noise surroundings even more than clerical workers and a mistake in judgment was much more costly than a clerical error.

Apart from the possibility of rectifying acoustical defects in existing buildings, the lecturer appealed to Engineers and Architects to always look into the acoustics of their important building schemes as it was actually possible to plan and allow for excellent acoustics in advance of construction.

A typical acoustic analysis of a lecture hall was demonstrated.

Mr. R. K. Nariman enquired if it would be ideal to have the speaker situated at the focus of a parabola. He also wanted to know if the current of air in an air conditioned room affected the acoustic properties of that room. He was afraid that acoustic materials would harbour germs and make the room unhygienic.

Mr. S. B. Joshi referred to the formula $T = \frac{05v}{\sum as}$ and inquired why the surfaces of innumerable particles in the atmosphere were not considered in finding the denominator "*as*" which would reduce T nearly to zero. He wanted to know the explanation of the whispering gallery at Bijapur. He referred to the great noise while travelling in a railway train and wanted to know if something could be done by improving the track say by using welded rails and timber sleepers.

Mr. F. E. Bharucha suggested the use of coir matting to reduce reverberation.

Mr. K. T. Divecha said that his experience about the use of coir matting was very satisfactory. He inquired if the absorption co-efficient of an adult would not depend upon the type of his clothes and whether the value 4·7 open window units found for European audience would equally apply to Indian audience—who did not use woollen cloths. He expressed the opinion that the application of the reverberation formula was not very easy, as it was difficult to ascertain accurately the absorption co-efficients of the materials used.

Reply—The lecturer in reply to the discussion said that air conditioned rooms did not present any difficulties as there was a great difference between velocity of sound and the speed of air currents. He assured Mr. Nariman that suitable acoustic materials from hygienic point of view were available. He informed Mr. Joshi that surfaces of only visible objects should be measured in applying the reverberation formula. He agreed with Mr. Bharucha and Mr. Divecha regarding the efficiency of coir matting as an acoustic material.

The Chairman (Dr. Taylor) in winding up the discussion said that the parabolic reflector would focus the whispers in the audience at the position of the speaker—a situation which no speaker would welcome. He said that the explanation of the whispering gallery at Bijapur was the cylindrical wall of large diameter so that the reflections along the periphery of the cylindrical wall never got away from it. The dome had nothing to do with the phenomenon. This explanation had been given long ago by scientists. In fact Prof. Sabine had actually designed a whispering gallery which had been constructed at Washington. He further explained that the higher frequency of the letter, "S" or a whisper was responsible for the phenomenon.

Referring to Mr. Joshi's pertinent question as to why the surfaces of innumerable particles in the air should not be taken into account in the reverberation formula, Dr. Taylor explained that substances whose dimensions were comparable with the wave length of sound could only affect the time of reverberation and the wave length of sound being of the order of one to two feet, very small objects did not count. He further explained this by an analogy with light waves. He confirmed the opinion expressed by others that coir matting was a very good acoustic material. He did not find any difference between the absorption co-efficient of an adult in woollen clothes or light clothes. He had experimentally found the co-efficient in the latter case to be 4·5. He thought the application of the formula was very easy, in fact he had roughly calculated the time of reverberation of the Institution Hall to be 1·3 seconds. Lastly he appealed to Engineers to give acoustic analysis an important place in their designs.

Engineers in the Making*

Mr. R. K. Nariman in the Chair

Mr. Shaikh in opening his lecture dealt fully, in the light of his fifteen years' experience of scientific engineering in his line with the training of an engineer. He described the present and past practices and how an engineer was trained in the past. In former days, he said, there were those who tried to navigate a ship without any knowledge of navigation. Such was the condition of engineers ; but now-a-days the engineer stood on safer grounds because he was equipped with best scientific training that was available at various Universities. He said that hard, intelligent work was always essential. Fat salaries did not come easily.

He then talked about personality, self-respect, vision, broad outlook, commonsense which marred or made an engineer. For future engineer he had a word of warning that the engineer could not be one who plodded along the tracks made by his predecessors, but one who could conceive new plans and strike along original lines to give increased happiness and comfort to mankind. He said that an engineer should have a strong confidence in himself and the future. He spoke of new openings for the budding engineers

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*A lecture given by Mr. A. A. K. Shaikh A.M.I.E., at a General Meeting held on the 25th September, 1941. Attendance 50.

and was of opinion that whatever calling, one wanted to follow, knowledge of engineering supplied a good grounding for a career, as it stood him in good stead in all branches of life, barring medicine. He said that the engineer should leave a heritage to succeeding generations in vastly increased value and potency of the spiritual and material welfare of the world so that the future would be happier and more comfortable.

To be a successful engineer Mr. Shaikh suggested ten qualifications, *viz.*, Power of decision, shouldering of responsibility, sensitiveness to human trait and character ; good manners, habits and appearance ; love of integrity, fairness and sincerity ; ability to teach, inspire and develop his subordinates ; strong analysing power, tact, self-control, should have plenty of commonsense and humour ; should be open to correction and physically and culturally sound and above all should possess a character which was the *sine qua non* of life.

He then made an appeal to the Heads of Departments to give opportunities to assistants of exceptional powers and concluded his lecture by quoting Omar Kayyum, that mathematician poet, as :—

"Think in this battered caravansarai,
Whose doorways are alternate Night and Day ;
How Sultan after Sultan with his pomp,
Abode his hour or two, and went his way."

and to his fellow-beings he said:—

"Strive, endeavour, it profits more,
To fight and fail than on this dull shore,
To sit and idle ever ;
For to whom he bears arm to the strife,
Firm at his post in the battle of life,
The victory faileth never."

An interesting discussion ensued in which Mr. F. E. Bharucha, Mr. C. H. Shah, Mr. V. R. Vaidya, Mr. S. B. Joshi, Mr. M. K. Surveyor and two guests took part.

The Chairman (Mr. R. K. Nariman) wound up the discussion by remarking that engineers alone were not to blame for the improper use of engineer's talents in destructive warfare.

Hyderabad Centre.

Celestial Surveys.*

Mr. Hasan Latif, C.E. (Lond.) in the Chair.

Rao Sahib T. P. Bhaskara Sastry referred in detail to the various determinations of the sun's distance which he stated was the unit in measurement of stellar distances and was considered to be the astronomer's yard stick. An important method of measuring that distance was by observation of Mars and some minor planets which came close to the earth at the time of Opposition. The minor planet Eros approached the earth to a distance of about 15 million miles at the Opposition of 1931 which afforded a specially favourable opportunity for the determination of the fundamental unit ; and it was expected that a very accurate value of sun's distance would be obtained when all the observations secured at the time were collected and discussed. The trigonometrical method of measuring the parallaxes of stars using the sun's distance from the earth as the base line, he stated, was applicable only to the stars very near the sun up to a distance of about 500 or 600 light years. Beyond that distance the astronomer had to resort to indirect methods. Some ingenious methods, had been developed which extended our knowledge to the remotest regions of the stellar system. The motions of stars supplied a powerful means of estimating distances in regions not too remote from the sun. He then referred to the distances of some well-known system obtained by this method—the Pleiades cluster, the Sirius-Ura Major cluster whose dimensions had been derived from the motions of the individual stars contained in the group.

After explaining the principles of the method of determining parallaxes of stars from an inspection of their spectra, the lecturer proceeded to give an account of peculiarities of the class of variable stars known as Cepheids. He remarked that the discovery of the period luminosity law in Cepheid variation had been of particular importance in the study of stellar system and showed how the parallaxes of distant clusters and the extra galactic nebulae had been derived from observations of the periods of the Cepheid variables they contained.

*A paper read by Rao Sahib T. P. B. Sastry, F.R.A.S. (London); F. N. I. Director Nizamiah Observatory, Hyderabad, before the Hyderabad Centre.

Referring to the spiral nebulae which were recognized to be external galaxies comparable in every respect to the Milky Way galaxy, Mr. Sastry described at some length the interesting phenomenon known as the redshift. The lines in the spectra of those nebulae appeared to be shifted from their normal positions towards the red, indicating a high velocity of recession and those velocities were found to be correlated with the immense distances at which the objects were situated. He showed how that relation had enabled astronomers to obtain estimates of the tremendously large distances which separated those nebulae which were in reality island universes from our system. It was by linking together data obtained from so many diverse sources that some knowledge of the dimensions of the Universe had been obtained, from which we could derive a fairly correct although fragmentary picture of the observable of the Kosmos as revealed by modern telescopes.

The lecturer concluded by referring to the close collaboration of the engineer and the astronomer in the design and construction of the various astronomical instruments without which much of the progress could not have been achieved and hoped that in India also (more especially in Hyderabad) such a collaboration would be possible, to the mutual benefit of Indian astronomy and Indian Engineering.

The lecture was profusely illustrated by lantern slides.

CEMENT CONCRETE SURFACING OF BEGUMPET ROAD*

Brief Technical Details.

Length of the Road	...	1 Mile, 5 furlongs, 504′ 6″.
Excluding the Bridge length	...	1 Mile, 5 furlongs, 54′ 6″.
Width of the Road	...	40′
Width of the Slab	...	18′ Thickness of slab 4½″
Rate per Sq. yard for 4½″ slab in 1 : 2 : 4 Mix :	...	Rs. 2-12-0.
Cost per mile	...	Rs. 30,000.
Duration of work	...	8 Months.

Preliminary.—The road from Begumpet to Secunderabad is the shortest route between Secunderabad and the localities of Begumpet, Amirpet, Somajiguda, Jubilee Hills, Khairatabad. It consisted of water-bound macadam surface, and was the only bit measuring 1¾ mile in length, which had not been dust-proofed between the terminal of the cement concrete road at the Hyderabad end and the spramex roads of Secunderabad Cantonment.

Traffic has considerably developed on this road due to following reasons :—

(1) Rapid development of Jubilee Hills locality.

(2) 1st class residents are drifting from the City proper to the suburbs.

(3) Begumpet Railway Station has developed into an out-going station for 1st Class Passengers going to Gulberga, Raichur, Bidar and Bombay.

(4) Development of Principal Begumpet Aerodrome of the State.

(5) Jagirdar College, the only Institution of its kind in the State.

* A paper read by Mr. Sadiq Ali Khan B.Sc. (Manchester) before the Hyderabad Centre.

Traffic statistics, tabulated below, taken on 2-3-1350 (Fasli,) between 8 A.M. and 6 P.M., will give an idea of the class and intensity of the traffic.—

Touring Buses 29 at 6 ton per unit	..	...	174 tons.
Touring Cars 386 at 2 tons per unit	...	..	772 ,,
Loaded lorries 77 at 4 tons per unit	...	...	308 ,,
Jatkas & Tongas 112 at ½ ton per unit	...	...	56 ,,
Carts 190 at 1 ton per unit	...	...	190 ,,
	Total	...	1500 tons.

Calculating per yard width of the road it gives 270 tons of traffic per day of 10 hours.

It may be regarded to be substantially heavy and of mixed character, ranging from ½ ton tonga to 6 ton Railway Bus.

It is developing day by day and arrangements have been made to record the census every six months.

History.—The metal belt of the existing road was 15′ wide. It was found that it was not possible to maintain the water-bound macadam in a good condition owing to the heavy traffic. The Government, therefore, sanctioned an estimate amounting to Rs. 56,000 for widening and improving the road. The width of the road was widened to 40′. When this work was completed, Government decided to cement-concrete the road. An estimate amounting to Rs. 80,000 was sanctioned for this purpose.

Survey Work.—Longitudinal Sections were taken every 30′ and cross section every 5′ to note the camber from point to point. The Longitudinal Section was drawn to the scale, taking 25′ to an inch horizontally and 2′ to an inch vertically. Great care was taken to minimise filling in lean mixture, and to have the longest possible grades without disturbing the existing metalled sub-grade. The camber was adopted as 1 in 80. The centre line was shifted at places to straighten the road. All curves laid were circular, ranging in radius from 1,500 to 5,000 feet. Vertical curves were provided at the junction of two grades to avoid bumping of cars. The minimum length of the chord taken was 30′ to suit the available length of channel form. There is a great cirticism about concrete roads that there are bumps at the joints. In the case of this road an attempt has been made to overcome this objection. Super elevation have been provided wherever necessary on curves.

Materials: Cement.—The cement used is slow setting Charminar Brand. The quantity of cement used was 607·50 pounds per cubic yard of finished concrete. The weight of 1 cu. ft. of cement is taken as 90 lbs. and content bag as 1 : 2 cu. ft.

Sand.—Kukatpally Nalla Sand was available at about 2 miles from the site. It was tested. It gave the following sieve analysis.—

Retained on	16 meshes	...	3·6%
,,	24 ,,	...	8·7%
,,	64 ,,	...	9·4%
,,	144 ,,	...	28·0%
Passed on	144 ,,	...	50·3%

It contained 10% of silt. When washed once it showed 7% and when washed twice it gave as 5%. It was fine, unsuitable for wearing surface and required more water for washing. It was available at site at Rs. 50 per 1,000 cu. ft. but washing charges were heavy.

The other sand which was used on the work was brought from Musi River, carted from Sangam, a distance of 11 miles from the site. Its cost was Rs. 100 per 1,000 cu. ft., nett.

It gave the following sieve analysis:—

Retained on	16 meshes	7% (Not used on work).
,,	36 ,,	13%
,,	64 ,,	11%
,,	144 ,,	25%
Passed on	144 ,,	44%

It contained 3% of silt. It was screened through 16 meshes and used on the work without washing. This sand was a little coarse, and gave a little rough surface, but consumed little water, resulting in greater strength.

The sieve analysis and the fineness modulus were as follows :—

Retained in	36 meshes	16%	2 7/32	Wt. in pounds
,,	64 ,,	30%	8 6/32	do.
,,	144 ,,	84%	15 1/16	do.
No.	100 ,,	100%	27 15/16	do.
			53 13/32	

Weight of sample	27 15/16 lb.
Weight per cu. ft.	92·4 lbs.
Voids percentage	47%
Fineness modulus	53 13·32
	27 /16 = 2 Approx.
This is satisfactory	This can be still increased to 2 25 by proper grading. Experiments are being carried out on Uppal road

∴ The sand was approved.

Coarse Aggregate.—Very good blue granite was available at 1 mile from the road. Metal was washed before use.

Grading of Aggregate.—Particular attention was given to grading of aggregate and the strength of concrete attained justified the care.

A cu. ft. of granite solid cube finely dressed, correct to dimensions weighs 166·0 lbs. The weights of aggregate and percentage of voids of different grades were as follows :—

Particulars of specimen.	Weight in lbs. per cu. ft.	Voids percentage.
3″ —2″ Granite Metal	87 25	
1½″ —1″ do.	83 00	50
¾″ —¼″ do.	82·50	53

The following proportioning were experimented upon :—

Percentage of 1½ metal in the mixture.		Percentage of fine metal in the mixture.	Wt. of 1 cu. ft. of mixture in lbs.	Percentage of voids.
(1)	80	20	92 1/8	44·64
(2)	75	25	95 7/32	42·70
(3)	70	30	95 5/8	42 40
(4)	50	50	98 5/8	40 60

The cost was also considered before deciding the proposal of grading the aggregate. The cost of fine metal is about 50% more than 1½″ metal. No. 2 mix was adopted taking 75% 1½% metal, and 25% fine metal. This gave an economical mixture.

Tests.—Test cubes were made out of concrete used on the work. They were made of 6″ size in the beginning, but were not tested as the machine in the Engineering College testing Laboratory is of 25 tons capacity only. Therefore 4″ cubes were made, but these too could not be crushed owing to the limited capacity of the machine. The results of tests are given on page 656.

There is a practical limit of lowering the quantity of water in a mix to attain the maximum strength, in view of workability method of tamping, grading of aggregate, and flushing of mortar at top. According to A.C.C. Pamphlet No. 23, by adding 6 to 6½ gallons of water, and getting slump from ⅛″ to ½″ a strength of about 2,800 lbs. ought to have been developed after 28 days. But it was noticed that an average strength of over 3,750 lbs. per sq. inch had been attained. This is mainly due to following reasons.

1. Perfect grading with very little voids gives dense mixture.
2. 1st Class aggregate.
3. Thorough mixing.
4. Clean aggregate.
5. Low Water Cement Ratio.

On Begumpet road, the thickness of mortar flushed out ranged from ⅛″ to ½″. The water cement ratio was controlled in such a way that thick mortar was not flushed out. In this connection the following observations were made :—

(1) To have a thicker coat of mortar it requires more water in the mixture to enable it flush out at top, thereby decreasing the strength.

(2) If more mortar is flushed out, it weakens the bottom layer.

(3) Where there is a thick coat of mortar at top, it is not possible to keep the metal at a level underneath, with the result that when the mortar wears out there is uneven wearing. The exposed metal is not maintained at level, and thus the surface becomes wavy.

(4) For flushing plenty of mortar fine sand is to be used. It requires more water. This weakens the strength of concrete.

Let me take the opportunity of bringing to the notice of engineers interested in the evolution of cement concrete roads, that in our State it has come to be a speciality, the credit for which goes to Nawab Ashan Yar Jung Bahadur, in whose time cement concrete roads were constructed on a large scale in Hyderabad, that concrete is tamped with heavy tampers,

Here we have been using tampers weighing 28 lbs. per rft. whereas in other parts of India tampers weighing 8 lbs. per rft. are adopted. There is an obvious advantage in heavy tamping, *viz.*, it gives a dense mix, but there is the handicap that it flushes out mortar and impoverishes the lower course. However both types of tamping need be tried for experiments. If cubes are cut from existing roads they would demonstrate the comparative strength of each road. On the Bombay—Poona Road, I observed that owing to the use of the vibrator the water cement ratio was reduced and strength was increased by 1000. This is worth trying on our roads. In the absence of vibrating machinery, the use of heavy tampers is the next best procedure.

Density of Concrete.—It is an axiom among concrete engineers that the denser the concrete, the greater the strength. The weight of concrete has a direct bearing on its strength. The weight of 4″ concrete cubes is tabulated below. Average weight of a solid piece of granite is 156 lbs, concrete cube is less by 4·2%. A deviation up to 5% is permissible as given by "Trautwine".

S. No.	Weight of 4″ cube in pounds.	Weight in lbs. in cu. ft.
1.	5 7/8	158·60
2.	5 13/16	156·924
3.	6·00	162·00
4.	5 13/16	156·924
5.	5 25/32	155·987
6.	5 13·16	156 924
7.	5 29/32	159 462
8.	5 23/32	154·413
9.	5 29/32	159 462
10.	6 1/32	162·837
11.	5 7/8	158 60
12.	5 7/8	158 60
13.	5 13/16	156 924

Water.—Filtered water was used for the concrete work. Mixing platforms were arranged at such intervals that the period between the mixing of a bath and carrying it to the site did not exceed 10 minutes. Every care was taken to deposit concrete in the bay within half an hour of mixing.

Tamping was done with a tamper weighing 28 lbs. per foot run. After $1\frac{1}{2}$ hours the concrete was covered with wet gunny bags. Ponding was done the next day.

Finishing.—The surface of the concrete was finished by means of wooden floats, and undulations tested with a straight edge of a steel plate of 10′ × 3″ × ½″ placed parallel to the axis of the road. The top was broomed to produce a uniform surface.

Method of Construction.—The length of the bays were kept 30′ and were laid on alternate bay system. Alternate bays were laid after 4 days. No expansion joints or Dowel bars were provided.

During the execution of work it was decided not to disturb the existing metal belt of the road. Undulations in the sub-grade were filled up with weak concrete.

A typical cross section of the road is shown on page 657.

Curing.—Curing was done by making Ponds on the concrete slab and kept filled with water for three weeks.

Chart.—Progress chart, and Section chart were maintained and kept upto date for ready reference. A specimen copy is furnished herewith. The progress chart gives the number of bays completed in a day. This also helps in fixing the date for removal of ponding.

Section charts give the thickness of each day tabulated serially from end to end. This also shows at a glance the time to lay the alternate bay and gives an idea of the work completed.

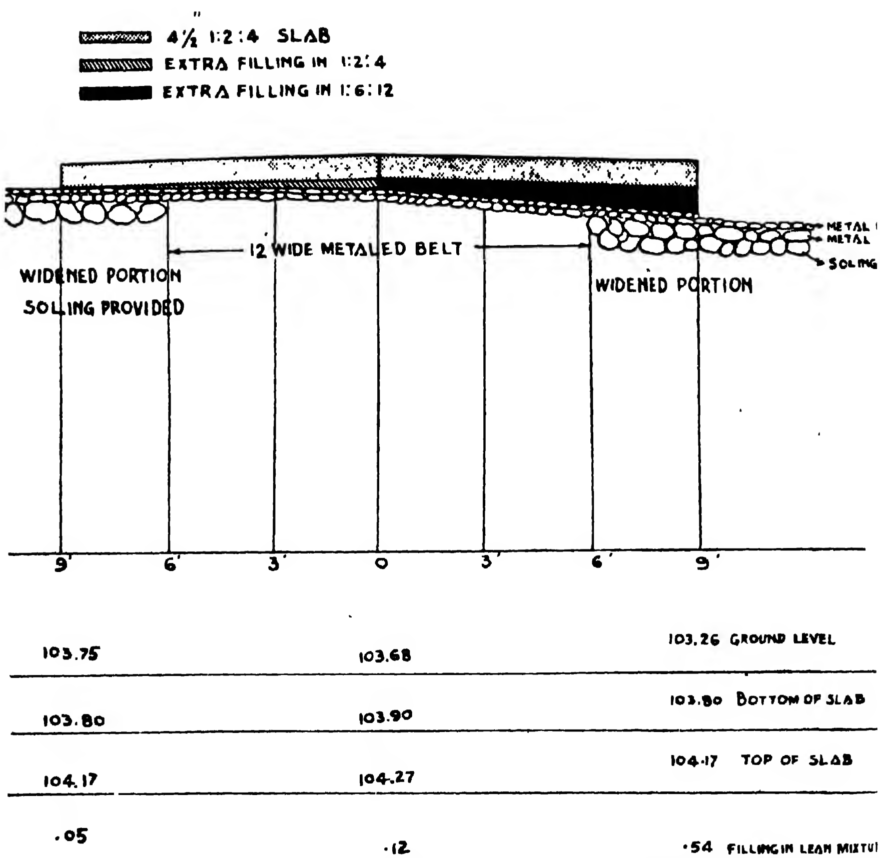
Out-Turn of Work.—The slab work was started on the 14th Shehrewar 1349 (Fasli). Being the rainy season the progress was not steady The work was completed on the 4th Khurdad 1350 (Fasli) *i.e.*, in a period of 8 months and 21 days. There were only 146 working days. The work had to be closed for some time, as the Railway gate was not widened in time.

The average per day works out to be 739 cu. ft. and the total quantity of work done is 1,07.676.0 cu. ft.

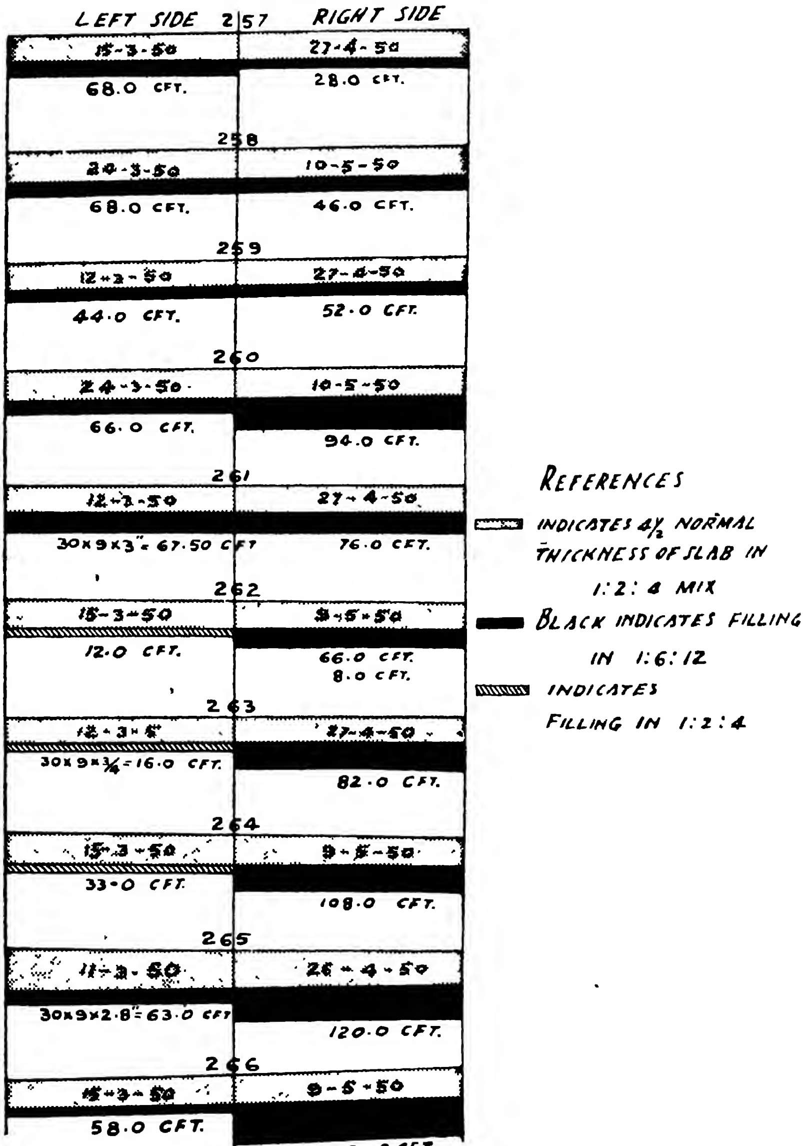
Statement showing the Results of Compressive Tests of Cement Concrete Slabs laid on Begumpet Road during 1350 (Fasli.)

S. No.	Cube No.	Date of making. *	Mixture.	Curving period.	Temp:	Total Quantity of water in gallons.	Slump test in inches.	Cracking strength lbs. per sq. inch.	Crushing strength lbs. per sq. inch.	Remarks.
1	23	5-3-1350F.	1: 2: 4	4 weeks	84°	5·74	$\frac{1}{8}$"	2500	Over 3750	
2	24	do.	,,	,,	84°	3·50	0	1500	,, 3750	Dry mix. gives low strength.
3	27	6-3-1350F.	,,	,,	84°	5·75	$\frac{1}{8}$"	2500	,, 3750	
4	29	7-3-1350F.	,,	,,	82°	5·50	0	2187	,, 3750	
5	30	8-3-1350F.	,,	,,	84°	5·50	0	1750	,, 3650	Same as No. 2.
6	32	11-3-1350F.	,,	3 weeks	82°	6·00	$\frac{1}{4}$"	2500	,, 3750	
7	23	12-3-1350F.	,,	,,	82°	5·75	$\frac{1}{8}$"	1875	,, 3750	Dirty & skimmed metal used.
8	37	18-3-1350F.	,,	,,	80°	6·00	$\frac{1}{4}$"	2375	,, 3625	
9	38	25-3-1350F.	,,	17 days	92°	6·50	$\frac{1}{4}$"	3250	,, 3750	
10	41	26-3-1350F.	,,	2 weeks	88°	6·25	$\frac{1}{4}$"	2500	,, 3750	
11	35	14-3-1350F.	,,	3 weeks	...	...	...	2031	,, 3750	Trap metal and sand brought from Bombay-Poona Road.
12	40	25-3-1350F.	1: 3: 5	2 weeks	...	..		1562	,, 3750	
13	25	6-3-1350F.	1: 6: 12	4 weeks	84°	5·50	0	1125	1360	
14	26	do.	,,	,,	84°	5·75	0	562·5	1296·20	Dry mix lowers the strength.
15	28	7-3-1350F.	,,	,,	80°	5·50	$\frac{1}{8}$"	1125	1510·60	
16	31	9-3-1350F.	,,	,,	72°	5·50	$\frac{1}{4}$"	1473·5	1610·60	
17	34	13-3-1350F.	,,	3 weeks	82°	5·50	0	1125	1463·70	
18	36	15-3-1350F.	,,	,,	80°	5·50	0	1125	1585·00	

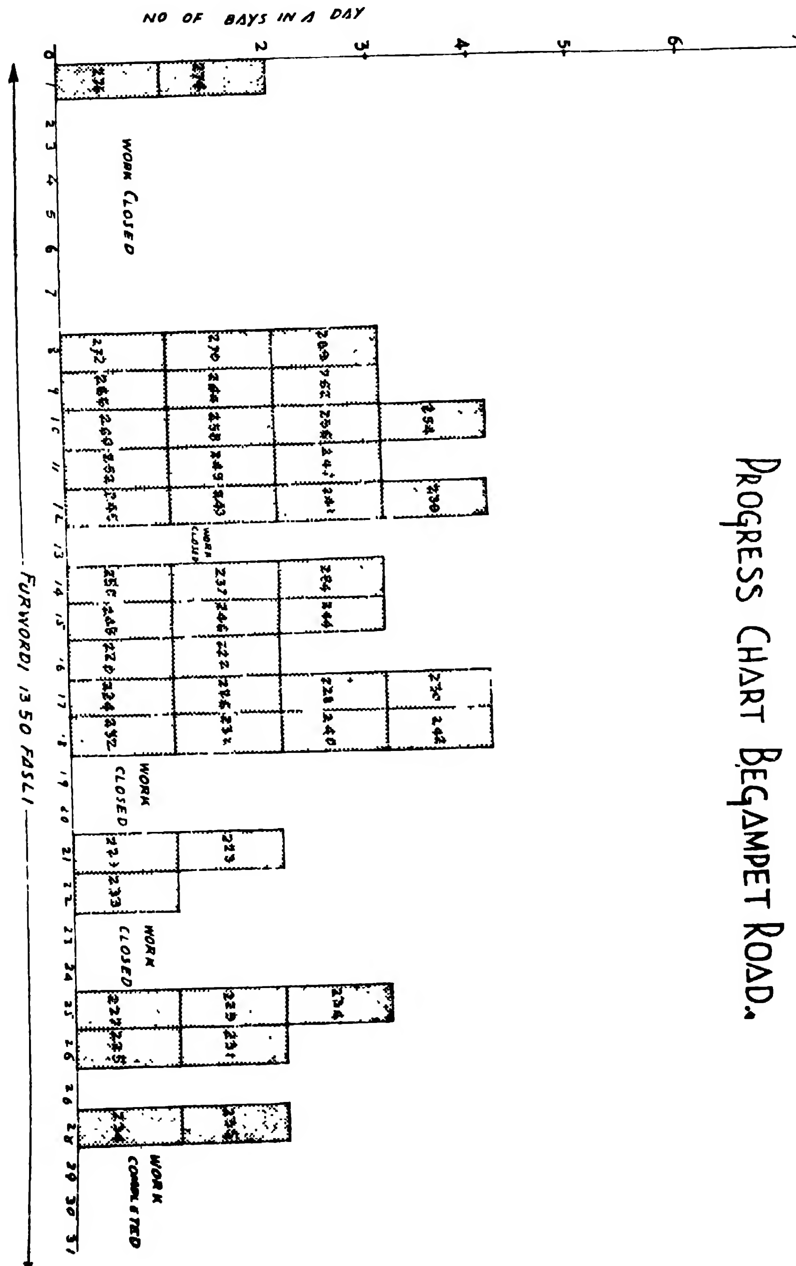
* These dates are given according to Mohamedan era.



TYPICAL CROSS SECTION OF BEGUMPET ROAD.



SECTION CHART BEGUMPET ROAD.



PROGRESS CHART BEGAMPET ROAD.

MAHABIR PRASAD, Esq., M.I E.
Chairman, U.P. Centre.
(1940-41.)

U. P. Centre

The U. P. Centre arranged an inspection trip to Latouche Road with a view to examine the construction of Bullock Trackways.

Mr. Mahabir Prasad and his assistant, Mr. S. C. Bose explained the method of construction to the members, which is briefly given below :—

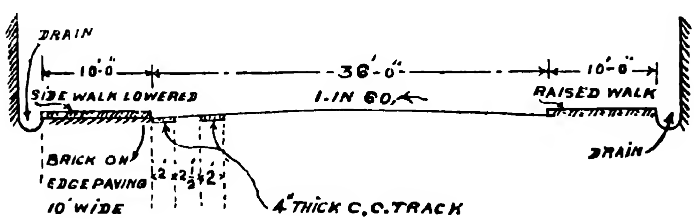
"The Latouche Road, Lucknow is surfaced with 2" to 3" T.R.A. premix laid in 1927. Undulations appear on the surface during hot weather owing to softening of the premix. This is specially noticeable on the heavy traffic side, *i.e.*, on the west side which is used by heavily loaded bullock carts from the Railway goods shed. A lot of patching has to be done throughout the year to keep the surface in a tolerably good condition. The cost of maintenance on this road is therefore very heavy. The traffic on this road is about 6,000 tons in 24 hours and consists of heavy bullock carts, trucks, buses and other light vehicles.

A cement concrete strip 9 ft. wide had been laid for a length of 2,640 ft. on the west side which is used by loaded vehicles from the station. It is 4 ins. deep laid on the old stone metal foundation. This 9 ft. wide strip has cost Rs. 3-8-0 per sq. yd. *i.e.* Rs. 3-8-0 per r.ft. of the track. Due to sewer and water mains running under the road on this side it was not feasible to lay a strip 9 ft. wide all along the length. As an experimental measure it was decided to try creetways *i.e.* 2 ft. wide C.C. strips 4 ins. thick, laid parallel to each other 2½ ft. apart. This arrangement will provide easy access to the sewer and water mains whenever necessary and the restoration of the road surface will be easier and less expensive. The work was completed about five months ago, and appears to be very satisfactory. All the heavily loaded vehicles going from the station to the city use the track owing to easier traction.

The cost of the track is Rs. 4-0-0 per sq.yd. of cement concrete portion including restoration of the premix edges. This works out to Re. 1-12-0 per running foot of track as compared to Rs. 3-8-0 per r. ft. of 9 ft. wide cement slab.

Two parallel strips 3 ft. wide were cut in the premix surface to a depth of 4 inches. The sub-grade was properly levelled and well consolidated so as to provide 4" uniform depth of cement concrete for the strips. Side forms were

fixed on either side of the two strips. As steel side forms were not available for the whole work and bricks were laid correctly according to levels and camber of the road with cement plaster on top. The cement concrete was 1 : 2 : 4 mixture with *Bharatkup* stone ballast and *Badausa* sand. The cement concrete was machine mixed and laid in the usual manner. Dalmia cement has been used in the work. The track was opened to traffic after curing for 28 days. The bricks used for side forms were taken out and the gap was filled with asphalt premix. A sketch of the completed section of road is given below."



SECTION OF CEMENT CONCRETE TRACK.

Members present were highly pleased with the works now being constructed under the supervision of the Public Works Department and there was some lively discussion in which almost all members present took part.

The U. P. Centre have sent the following Report on the experiment carried out on the Kaisarbagh Main Road, in Lucknow District, with Proctor's Cold Premix Carpet. Length 1 furlong 390 ft. The experiment was conducted by the Superintending Engineer, P. W. D., U. P.

Existing Surface—Brick ballast painted.

Width—The road was originally 20 ft. wide and no change was made in width.

Foundations—No new foundations were given.

Wearing Coat—The road surface was thoroughly cleaned, patched and brought to true formation and camber with Proctor's cold emulsion made from 50 : 50 Socony Asphalt, grade 105. A tack coat was then applied over which a carpet $1\frac{1}{2}''$ thick before consolidation was laid and consolidated thoroughly with a 8-10 ton Diesel Oil Engine roller and then blinded with *Bharatkup* stone grit $\frac{1}{4}''$ to $\frac{3}{4}''$ (not well graded).

The quantity of cold emulsion used was 7 lbs. per cu.ft. of stone chips or 0·40 gallons per sq. yd. and 12·5 cu. ft. stone chips were used for every 100 sq. ft. of road. The total quantity of emulsion used works out to 1-1 gallons per sq. yd. and is inclusive of emulsion used in patching and tack coat. No seal coat was given.

Cost—The total cost of the work was Rs. 3,021 or Re. 1-4-7 per sq. yd.

Other Data—The work was started on May 27, 1938 and completed on June 13, 1938.

There were a few showers of rain while the work was in progress.

After nearly 3 months, indentations in the surface were repaired with the same material and the conditions of the road surface was found to be fairly good. In January 1940, after say 1 year 8 months of the initial work, it was found that a few patches had to be repaired in short lengths, which were affected by heavy rain during construction ; else the condition of the road was found good. In April 1941, after say 3 years of the initial work, it was found that the surface was wearing in patches. The patches show that there is a very little binder in the premix carpet. No seal coat was provided originally and it is likely that the surface was not waterproof. It is proposed to provide a seal coat this year with Socony Asphalt at about 0·24 gallons per sq. yd. covered with *Bharatkup* stone chips $\frac{1}{8}$" to $\frac{3}{8}$" gauge well graded.

Total traffic on this road is heavy town traffic and is 4,400 tons per 24 hours according to a recent census.

WORLD NEWS

OF

ENGINEERING INTEREST

Making Armaments in India

Civil Industry Plays its Part.—The manufacture of steel buildings, engineering supplies and many items of weapons and ammunition is now in progress by civil industry in India in addition to Government factories. The object is to make the maximum use of the existing industrial capacity and make India self-supporting for munitions supply as far as possible.

Large orders have been placed with civil and railway workshops for the production of parts of armaments. The production of 4·5 inch howitzer and 25-pounder shell forgings in railway workshops has been established, and jute mills have undertaken machining of shells as well as further work in munitions supply.

Some workshops have been entrusted with the manufacture of empty fuses for high explosive shells.

Shell Production.—Various schemes for shell production have been introduced which differ according to the facilities available in each particular area. For example, in the Bombay circle half wroughts in the form of pierced forgings are being supplied by the Department of Supply, fabrication of the forgings taking place in Bengal, where ample materials and capacity for this class of work are available. The forgings are delivered to Feeder Workshops, so named because these workshops, although not equipped with plant suitable for completing the whole machining process, are quite capable of undertaking the early operations, including finish boring prior to what is known as "bottling" or "heading."

The shells in this condition are transported from the feeder workshops for a further process leading up to the finishing stage. Government Inspectors are stationed at the major workshops, where the shells are examined before further work proceeds.

Major workshops undertake the next six major operations on the shell. These workshops are best fitted for these operations because they possess adequate hydraulic power and sufficient plant to cover the machining operations prior to finishing

Finishing the shell is undertaken at a central workshop. This workshop has been equipped for banding and band forming of the shell ; fitting and rivetting the baseplate ; thread-milling the fuse hold ; sand-blasting and varnishing the cavity and preparing the finished shell for final inspection and delivery to the Government depot.

Central Workshop in Calcutta.—In Calcutta all stages from the forging to the finished shell are done in a central workshop, in which have been concentrated very large numbers of lathes generously loaned by the Calcutta Jute Mills. Shell production is also taking place in two major railway workshops in the Calcutta area, two in South India and three in Northern India. Several feeder workshops for machining "roughs" are established among smaller firms in the Punjab and Calcutta, while complete 18-pounder shells are being produced in large quantities in Calcutta by engineering firms and one railway workshop. Another Calcutta engineering firm is well ahead with the casting and machining of mortar bombs.

Other firms with plant of a lighter type have been given orders for the machining of baseplates from stampings made elsewhere in India.

The finished empty shell is then sent for filling at an Ordnance Factory.

Before full expansion has been reached in Bombay, the scheme will include lathes loaned to Government by mill owners of Bombay and Ahmedabad. These machines will be adapted for war work and after the war will be returned to their owners.

A further phase in shell production will embrace more railway workshops and civil firms in Gujrat and Kathiawar.

Fuses.—Certain fuses are to be made in Bombay and Calcutta, partly from materials—in the form of extruded bars—from elsewhere in India. Some of the smaller components will be made in Bihar, Madras and the Punjab, as machines suitable for their manufacture cannot all be found centralised. The workshops to be engaged on this work will machine the

parts entrusted to them and a central workshop in Bombay will collect them for thread-milling and to apply protective coatings before despatch to the Government depot. The fuses will then be sent to an Ordnance Factory for filling. Fuses are complicated work one of them having no less than nineteen component parts.

Brass bars for tne main component will be cast in chilled cast iron moulds, cut into billets and stamped into half wroughts for machining in capstan lathes. Copper and brass strip will also be rolled from billets cast in Bombay, Calcutta, Lahore and Ajmer.

The steel components of the fuse will be made from special steel bar rolled by Tatas. Bombay has no potential capacity for producing bars from the class of steel required.

Exhibitions.—To establish manufacture by the trade of certain items of Army equipment previously manufactured in Ordnance Factories only, exhibitions have been held in Calcutta, Lahore, Bombay, Nagpur, Madras and Cawnpore. In all, no less than 437 items normally manufactured in Ordnance Factories have been placed with trade and railway workshops.

Capacity surveys were carried out in over 300 engineering factories and railway workshops. Initial orders were placed to the value of Rs. 8,00,000 for shell forgings and machined shell bodies. Additionally, a number of railway engineering shops embarked on the production of shell gauges and the manufacture of hand grenade bodies. A Bombay firm received orders for the making of ammunition boxes, while in the Calcutta area private enterprise undertook the production of certain tools for Ordnance Factories, and an experimental order was placed with certain firms for copper driving bands for shells.

Other Orders.—Other orders include heel and toe tips for boots (2,500,000 pieces), 25,000 bits and 50,000 stirrups, non-ferrous production orders, brass ingots and strips. Supplies of copper ingots were arranged in the Bombay area.

Shortly after the outbreak of the war, the Railway administrations offered surplus manufacturing capacity of their workshops to be utilised for the production of munitions and armaments and other work connected with the active prosecution of the war. During the first year of the war, large orders for war materials were in hand. They included the manufacture

of 1,50,000 tent poles, 1,200 motor vehicle bodies, firing platforms, trench mortars, gauges for munition manufacture, machine tools, S.A.A. tools, several lakhs of grenade bodies and components, ammunition boxes, thousands of stirrups and bits, steel huts and flannel shirts. Over 1,600 tons of wood were sawn into scantlings.

These orders were placed in the comparatively early stages of the war production drive, since when substantial advances have been made under the Director-General of Munitions Production in the conversion of India's engineering resources to the production of war requirements. Subsequently, a committee of industrialists was appointed to advise the Director-General on major munitions problems.

Reprinted from "The Indian and Eastern Engineer" Calcutta, August, 1941.

The Engineer and His Place in the New World Order*

1. Between the master mind of the scientist, often a theoretician, who, by his researches, uncovers some fundamental principle in the realm of nature, and the "industrious mechanic", who constructs the machine embodying that principle, there comes the engineer, who is the important link between the two. In him are combined, in fitting proportions, both the theoretical and the practical ; he is truly an applied scientist. He it is who makes possible the realisation of the dreams of the pure scientist, and, in so doing, must himself exhibit considerable vision and ingenuity—whence his title, as we are reminded from time to time.

The engineering profession has, therefore, played a major and indispensable part in achieving this amazing development of the past century and a half.

A decade ago it would have been possible to pronounce without hesitation that, while the outstanding advances made by our civilization have wrought problems, nevertheless, the balance has definitely been on the side of rendering great service to mankind. To-day however, there may be some reasonable basis for doubt regarding the truth of such a pronouncement. With such refinements of devilry as the bombing aeroplane, the handiwork of our profession, being used to destroy so many of our finest positive achievements,

*Brief abstracts from Mr. J. Rankin's address, Chairman Sydney Division of the Institution of Engineers (Australia).

it may rightly be questioned whether, when the history of the power age comes to be written, the verdict may not be otherwise.

It would appear that, if the engineer is to take a great deal of the credit for the benefits conferred on man, he must likewise accept a large share of the responsibility for much, which has not been in the best interests of the race. And yet it must be remembered that the services of the profession are also available to minimise, if not entirely to circumvent, the worst effects of the destructive forces, which have been unleashed against humanity. The speedy devising of the "de-Gaussing" equipment to protect shipping against the ravages of the magnetic mine is a case in point. Then again, on a wider scale, the engineer has achieved a great deal for the protection of personnel and property against death and damage from the air. He is only limited in this work by the amount which the community is prepared to spend ; if the powers-that-be deemed that the question of paramount importance was the most complete protection of the great masses of the people, then the engineer would be technically capable of achieving such a result.

In endeavouring to make a final decision as to the true position of the engineer in relation to society, it may be considered that he has been the unquestioning servant of the community ; he has striven to give it what it demanded, whether good or ill. A very laudable attitude for a servant, no doubt, but all the questions involved are not disposed of merely by acknowledging that fact. Obviously the engineer has given to society machines and contrivances, for the proper use of which mankind has not, in the mass, developed an adequate moral standard.

2. As men everywhere to-day are discussing the new world order, which they believe will come when the clouds of war have rolled away, and as such a development is a logical expectation, if life has any forward-looking purpose, it may be seen that the grand consummation of the engineer's service for humanity probably lies in the future.

For engineers the crux of the whole question is whether they will continue to be the dutiful servants of the race and carry out their masters' bidding, or whether they shall not have the right to determine how their handiwork shall be employed. Referring again to the moral issue, there is always

the danger, as suggested earlier, that the aeroplane, which is constructed for greater ease and speed of peace-time communication, and the high explosive, which engineers employ for the more effective carrying out of large constructional works, may be combined in perverted form to produce the bombing aeroplane. The danger is ever present so long as engineers remain only servants. It would hardly be suggested that the solution is that which appealed to Butler's Erehwonians and that all production should cease and all machines be destroyed because of the inherent risk. The alternative is that we should not only serve, but should also be given the opportunity to lead. As leaders we should insist on our talents being used only for constructive ends. Such an attitude would pre-suppose that the engineer possesses the necessary qualities of leadership and that engineers as a class are capable of that degree of co-operation which would make such a stand a matter of unanimous decision.

3. The reason for these professional characteristics is not difficult to discover. While the particular mentality of the engineer probably determines his choice of calling, it is above all his training which gives to his mental processes a characteristic direction. Is not his manner of approach to his problems scientific and sensible? His first step is to define clearly what he is attempting to achieve then to survey present resources and those which he is able to acquire; next to plan the most effective way of attaining the objective with the means at his disposal; and finally to get on with the job.

This is no hit-or-miss method. He knows what he wants and, usually, how to obtain it; if not, he knows how to go about discovering a way, if there is one. What a striking contrast with the accepted methods of carrying on the affairs of the community. Here there is an absence of a grand unifying purpose, no effective use of our resources of men and materials ; so much to do, so little done.

The effects of this policy of drift became more apparent in the quarter century of fitful peace which was sandwiched in between the two world wars. Here were all the symptoms of the phenomenon of "plenty-poverty." Overproduction at one end of the social scale and under-consumption at the other ; young men with the will and capacity to work but no work for them; the development of marvellous machines which were capable of producing more and more useful articles at cheaper

cost, but, at the same time, adding to the army of unemployed, who became increasingly unable to purchase what had been produced. The explanation of the extraordinary progress of this century and a half is that its driving power has been the urge of the private profit motive, which has even endowed universities and research workers, and has achieved much positive good. Yet it has produced more social problems than it has solved; the search for new markets, and inevitable result of overproduction, has been a fruitful cause of international conflict. In a highly industrialized country like the United States of America an intensification of the problem is found in that approximately 90 per cent of the national wealth is in the hands of only 2 per cent of the population ; and the situation is little better in Britain. This development has not produced commensurate community benefits and is the result of the absence of planning on a national scale—it has just happened.

If the growth of such difficulties has been possible in a period of comparative peace, we can hardly imagine the social conditions which will prevail after the conclusion of the present world upheaval, if the same haphazard methods are retained. The transition from a non-productive war economy to a normal peace-time one, with whole communities resuming their places in commerce and industry, will produce problems which may prove to be well nigh insoluble, unless wise counsels anticipate the probable trend of events and forestall the worst effects.

To acknowledge the symptoms of maladjustment in the social system it is not necessary to subscribe to some irresponsible financial nostrum. It is merely to face facts. And in pursuance of this attitude we must recognize that we are in the midst of the greatest conflict of all time. If we are to play a major part in providing the sinews of war, we should logically demand a rightful place in the task of determining the character of the ensuing peace.

4 Assuming that we succeeded in fitting ourselves for these wider responsibilities, what world situation would we then possibly face? Among our resources we should reckon a great wealth of human ability and a rich endowment of nature's material gifts. Our problem would be to bring these together in fruitful union, a result, which, too often, has not been achieved under the methods of the past and present.

5. If we are prepared to go forward and to perform faithfully the task nearest to hand with vision and purpose, we shall still be servants, but in a higher sense than we have ever before realized.

Oil-Burning Locomotives for the Andes

Two locomotives to cross the Andes over the highest railway line in the world are to be made in Great Britain. They are for the Central Railway of Peru, the summit of which is 15,806 ft. above sea level, the greatest height of any standard gauge railway anywhere.

The line has 41 bridges, 61 tunnels and 13 reversing stations, and it twists up the Andes for 74 miles of practically 1 in 25 grade. The engine load required is from 350 to 400 tons. The locomotives ordered are 2-8-0 engines of general utility type for passenger and goods trains, with tenders arranged for oil-burning and weighing 174 tons each. Nine such engines, specially designed for the extremely severe conditions, have been supplied to the Central Railway and three similar units to the Southern Railway of Peru. The latest order will make a total of fourteen ordered by Peru in the last five years, apart from four articulated locomotives for goods service.

Reprinted from "The Commercial Bulletin" July-Aug. 1941.

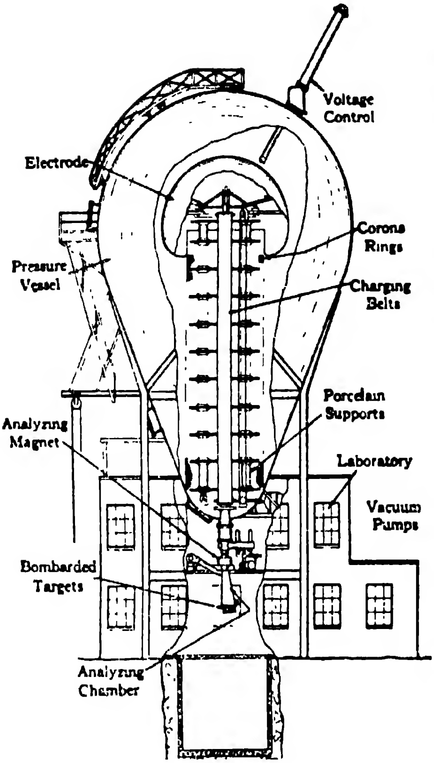
World's Largest Water-Supplier

The largest hydrostat installation ever planned is being built in Scotland for Bariloche in the Argentine.

The new installation will supply a high level reservoir at 861 metres through 400 metres of 150 mm. piping and 1,845 metres of 175 mm. piping. From the intake to the hydrostat station the motive water will flow at the rate of 4,600 litres a second.

Reprinted from "The Commercial Bulletin" July-Aug. 1941.

The Machine for Smashing Atoms



The Atom Smasher at East Pittsburgh is of the pressure electro-static type. In the steel "pear" or pressure tank is located the apparatus for making and firing the nuclear "bullets", while in the two-storey brick building at the base are the auxiliary devices, the targets, the measuring, and the recording devices. Electric charge is carried from a generator at the base of the tank by two belts running up to the electrode at the top where the charge accumulates on its outer surface, creating a high potential between electrode and ground. In the electrode and arc discharge is maintained in hydrogen. This produces hydrogen ions, *i.e.*, hydrogen atoms minus their electrons, and deuterons, which are double-weight hydrogen atoms minus electrons These ions—the prospective bullets—start on their trip down the vacuum tube, which stands in the centre behind a charging belt. Directed at the targets at the bottom of the tube, the ions are accelerated en route by the electric field created by the high voltage.

Such a source always produces a mixture of several kinds of ions, so the beam is passed between the poles of an analyzing magnet. Here the light-weight ions are deflected more than the heavy ions and the kind that is sought comes out of one of the portholes in the analyzing chamber. Here they strike the targets, and here the atom smashing occurs.

Reproduced from "The Westinghouse Engineer" May, 1941.

Detection of Imitation Gems by Cathode Ray

Imitation sapphires can now be detected in a few seconds by the cathode ray tube. The commercial use of the apparatus for this purpose is the result of the research work of Dr. W. D. Coolidge in the laboratory of the General Electric Company, London, who themselves use more than 1,500,000 sapphires, which rank next to diamonds in hardness, as jewels for bearings in meters and other delicate electrical instruments.

Imitation sapphires are easily detected. Trays carrying both real and false are exposed in a dark room for a few moments to the powerful rays from the tube. All the jewels glow or radiate colours while exposed to the rays. When the rays are turned off the natural stones cannot be seen; the synthetic keep on glowing. The rays even help to detect where the natural or factory made gems come from.

Reprinted from "The Commercial Bulletin" July-August, 1941.

Robot Lighting Plant.

Port Macquarie, a small seaside town in New South Wales, is to be lighted by an electrical generating plant which runs itself. The motive power consists of two Blackstone 6 cylinder 240 h.p. engines. The plant is required to be capable of functioning unattended and the necessary mechanism has been duly devised. If there is a rise in the temperature of the engines' lubricating oil, the absentee attendant will hear an alarm.

So, if there is any failure of the water cooling system, or overloading, or overspeed ; failure of oil pressure, or too rapid drop in the temperature of the water of the cooling system, forth will blare the warning signal. If nobody hears the warning the engines will stop work within five minutes.

Reprinted from "The Commercial Bulletin" July-August, 1941.

New Chemical Micro-Analysis

Mercury Drops and Electricity Quickly and Accurately Measure Billionths of an Ounce of Substances—A simple method by which electricity measures chemicals in infinitesimal amounts was recently described before the annual meeting of the American Chemical Society as a means of speeding up

scientific research. While ordinary chemical analysis involves many intricate and laborious operations, the new technique described by Dr. Langer, Westinghouse research chemist, measures substances indirectly by recording tiny electric currents passing through the solutions being tested.

The essential parts of the apparatus known as the Polargraph, are a reservoir of mercury, a small storage battery and various electric meters. The mercury is fed through a tiny glass nozzle, in droplets no larger than a head of a pin, the solution being tested. When electric voltage from the battery is applied to the solution, a chemical change takes place on the surface of the mercury drop that is about to leave the nozzle. A new drop is formed every few seconds to maintain a clean surface for the chemical action.

To measure, for instance, the amount of copper in the solution, the electric voltage is set at the specified amount for that substance as you would tune in a radio to a certain station. From a dial the amount of current passing through the solution is determined, which indicates the amount of copper it contains. A solution that contains many substances may be analyzed by "tuning in" voltages corresponding with the various substances.

The Polargraph has already been used, to measure amounts of several dozen substances and can probably be applied to many hundreds after further research has revealed the standards of voltage and current for each material.

The measuring apparatus has been used in a few European countries but has not as yet received full attention. Dr. A. Langer, who described the device, became interested in it through his acquaintance with the inventor, Professor J. Heyovsky, and believes it holds great possibilities in simplifying the work of medical scientists and biologists.

Reprinted from "The Westinghouse Overseas Letter" July, 1941.

Invisible Light Decorates Theatre

Unique lighting effects were recently achieved in a new California theatre by the use of invisible ultraviolet radiations. This theatre is among the first to take advantage of the capabilities of ultraviolet to produce beautiful effects on flourescent paints.

Eight ultraviolet lamps are used to activate flourescent pigments on the wall and ceiling. When the house lights are turned off, scrolls and paintings glow with soft pink and green visible light, giving unusual lighting effects.

Reprinted from "The Westinghouse Overseas Letter," June 1941.

Miniature Lines Give Lightning Protection Data

Models of transmission lines and man-made thunder storms are enabling Westinghouse engineers to discover new ways of guarding power-transmission system against damage by lightning.

During three years of research, Dr. C. F. Wagner and Gilbert D. McCann have observed 15,000 strokes of artificial lightning on these diminutive power lines while they experimented with grounded overhead wire to protect the power carrying wires. Their experiments were not only concerned with the fundamental problem of maximum shielding but also the variables : different heights of clouds, two polarities of strokes, configurations of the power conductors, the effect of distance from ground wires to the true ground plane, the influence of steep hillsides and valleys, the significance of wind and many others. Results disclosed the proper placement of these overhead wires to give high tension conductors the greatest protection against 20,000,000 volt natural lightning strokes.

The two engineers create their artificial lightning storms with a surge generator which can build up 3,500,000 volt charges on its capacitor plates. An electrode serves as the "thunder cloud" from which lightning strokes 20 inches to 13 feet in length were used.

During the experiments the model power line is struck from all possible angles. The engineers then observe whether the ground wires, running parallel above the power wires, shield the system by absorbing the bolt and carrying it harmlessly to the earth, without producing overvoltages in the power conductors that will result in flashovers.

Ever since the acceptance of the direct stroke theory of lightning protection it has been possible to design lightning proof transmission lines, but it usually is not economically

feasible to build lines according to such design. Nevertheless it is possible to predict with statistical accuracy how many outages per year per hundred miles of line will occur for any given set of transmission line characteristics.

Reprinted from the "Westinghouse Overseas Letter," June 1941.

Engineering Economic and Aesthetics

Courses of Instruction at Cambridge University—The Council of the Institution of Civil Engineers have recently given consideration to the need to foster amongst engineers the closer study of (a) the economics of engineering projects ; (b) the organisation and management of engineering work, and (c) the relations of aesthetic considerations to engineering design and construction.

In the past these three subjects have not generally been included in an engineer's education and training, but have been left to be acquired by practical experience spread over many years. Together they include many aspects of engineering work which require to be kept continuously under review in the light of changing economic conditions and the incidence of scientific research on the use of materials and on design.

The Council believe that in the period of reconstruction and development which will follow the present War, these subjects will become of increasing importance, and in the national interest should form a part of the equipment with which engineers should be furnished in order that they may adequately play their part in the task before them.

The Council accordingly intend to examine all possible means by which the Institution can influence the better understanding of engineering economics and aesthetics, not only by students resident at the Universities, but also by those otherwise engaged in their engineering training, so that eventually a study of these subjects may form an integral part in the recognised education of all engineers.

As a commencement the Council approached the Vice-Chancellor of Cambridge University with an offer to finance for a period of five years a lectureship on the subjects envisaged in the hope that they would in due course form part of the engineering curriculum of the Mechanical Sciences Tripos.

The proposal was cordially welcomed and has now been accepted in principle by the Council of the Senate of the University, but its full adoption will necessitate some re-consideration of the scheme of instruction in the Engineering School and possibly of the Mechanical Sciences Tripos, which it would be impracticable to undertake in wartime. It is proposed, however, that a beginning should be made in the next academical year, commencing in the autumn by inviting a number of eminent engineers and others to visit the University to give either single lectures or short courses on subjects coming within the terms of the proposal.

Reprinted from the "Road & Roads Construction" London, July, 1941.

The following new American Standards have recently been issued :—

1. Proposed American Standard for A C power Circuit breakers (published for trial and criticism).
2. Proposed American Institute of Electrical Engineers Standard for apparatus bushings.
3. Report on proposed standard for Protector tubes.

Reference to Interesting Articles

1. An Outline of Town Planning—*Proceedings Punjab Eng. Congress*, 1940.

2. Construction of Cement Factory in Patiala State—*Proceedings Punjab Eng Congress*, 1940.

3. Earth's Crust Resistance & Lightning—*The Journal of the Engineering Institute of Canada*, April 1941.

4. The Construction of the Milwaukee water purification plant—*Journal of the Western Society of Engineers*, February 1941.

5. Salts in Irrigation Water—*Proceedings American Society of Civil Engineers*, June 1941.

6. The Benzol Plant—*Tisco Review* of September and October 1941.

7. Road Traffic Calculations—*Journal of the Institution of Civil Engineers (England)*. June 1941.

8. Commutating windings for A.C. Machines—*Engineering London*, July 11, 1941.

9. Use of Reinforced Concrete in Marine Structures—*Proceedings of the New Zealand Institution of Engineers*, July 1941.

10 The Fundamentals of Steam Turbine Governing—*The English Electric Journal*, June 1941.

11. Arc Furnace Transformers—*The English Electric Journal*. June 1941.

12. The nature, cause and prevention of Resonant Vibration in suspension Bridges—*Journal of the Western Societies of Engineers*, April 1941.

13 Proportioning of Concrete with special reference to the grading of aggregate—*Transactions of the Institution of Engineers (Australia)*, Aug. 1941.

14. Line constants and circle diagrams Simplified—*The Westinghouse Engineer*. August 1941.

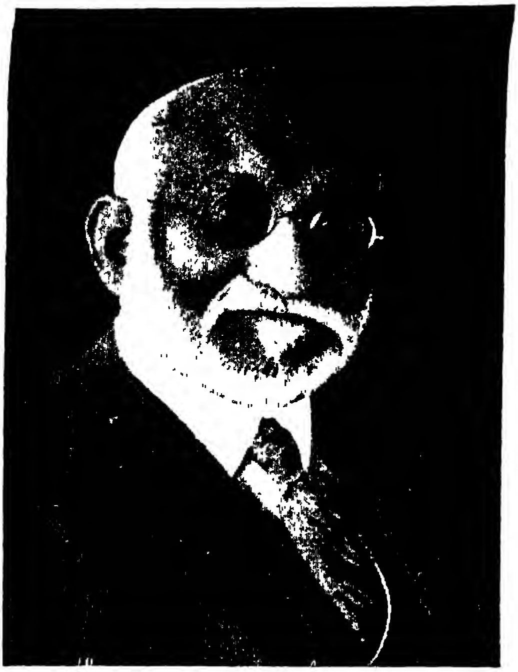
15. Concrete Air Raid Shelter built without steel reinforcement—*Indian Concrete Journal* October 1941.

16. Industrial Lighting for War Conditions—*B. T. H. Activities* July 1941.

17. The Metrovick "Mulligan" power factor correction calculator—*The Metropolitan Vickers Gazette* July 1941.

18. Air Traffic Control—*The Engineering Journal.*

"The Engineering Institution of Canada" August 1941.



The Rt. Hon'ble
Sir Akbar Hydari, P C.
Kt. D.C.L., L L.D.

Mr. Syed Ali Raza,
B A., B.Sc. (Hons.),
A M.I.C E., M.I.E.

LOCAL CENTRES

HYDERABAD CENTRE

******Your Excellency, Ladies and Gentlemen.***—On behalf of the Hyderabad Centre of the Institution of Engineers (India) it is my very pleasant duty to accord a most cordial welcome to Your Excellency, and to convey to Your Excellency the deep sense of appreciation of the Engineers of this Centre for the signal honour that Your Excellency has done to them by accepting to become an Honorary Member of the Institution of Engineers. It is a matter of gratification to the Engineers in India, and in particular to the Engineers in the service of H. E. H. the Nizam's Government, to see that Your Excellency is the first Indian to find a place of honour in the list of the Honorary Members of the Institution of Engineers which is adorned by the names of illustrious Indian Viceroys from His Excellency Lord Chelmsford down to the present Viceroy, His Excellency Lord Linlithgow.

Your Excellency, the Institution of Engineers (India) was established in the year 1920, and was formally inaugurated by His Excellency Lord Chelmsford on the 23rd February 1921. The foundation stone of the building of the Institution was laid at Calcutta by His Excellency Lord Irwin which was formally opened by His Excellency Lord Willingdon in 1931. The Institution was granted a Royal Charter in 1935. It has local centres at Calcutta, Bombay, Madras, Lucknow and New Delhi. Among the Indian States, Mysore and Hyderabad have been privileged to establish local centres. The Hyderabad Centre which was inaugurated by Your Excellency on 15th November 1938, though still young, has every hope that, with the blessings that it received at your hands, and the encouraging support that it has been receiving from the Public Works Ministers, notably the Hon'ble Raja Dharam Karan Bahadur, it will continue to do increasingly useful service in the cause of the progress of the Engineering Science, which is a *sine qua non* of the moral and material advancement of any country.

* Mr. Syed Ali Raza's (Chairman Hyderabad Centre) address on the occasion of "At Home' to The Right Hon'ble Sir Akbar Hydari, P.C., Kt., D.C L., LL.D.

The progress made by Hyderabad during Your Excellency's regime, both as a Finance Member, and as the President of the Executive Council, is writ large in the history of its Engineering Works. The expansion of the Road and the Railway system in the State, the construction of large bridges such as those of the Bheema, the Godavari, and the Krishna, the construction of numerous irrigation schemes, most important among them being the Nizamsagar Project, the schemes for the Water Supply to district towns and rural areas, the Osmania University for expanding the education in the State, Industrial concerns such as those of Sugar, Paper and Cement, are but a few items in the list of the beneficient activities which have been undertaken during the illustrious rule of our benign Sovereign, and with which Your Excellency has been associated both as a Financier and an Administrator.

As Engineers we cannot lose sight of the fact that side by side with these schemes of to-day, there have been laid, under Your Excellency's far-sighted statesmanship, seeds of future prospect of this State in the active formulation of schemes such as those of Irrigation for the Tungabhadra, the Krishna and the Godavari, the generation of electric power from these future reservoirs, the formation of an electric grid over the whole State, and so many other measures which are necessary for the industrial, social and cultural development of our State. No wonder then that we should regard Your Excellency, which we sincerely do, as an Engineer in the real sense, because you have not only devoted your lifetime as a "Builder" of the fabric of which we are proud, but as a far-sighted "Designer" you have laid those foundations on which would rest, with ever-growing strength, the future prosperity of this land.

I fear I have taxed Your Excellency's valuable time, but Your Excellency will forgive our exuberance of feeling when we say that in doing honour to Your Excellency the Institution of Engineers (India) has paid a tribute of honour to the progress made by Hyderabad during the last 25 years through its varied and numerous Engineering Works

***His Excellency's Reply.**

His Excellency rose amidst cheers and replied as follows :

I must express to the Institution of Engineers my thanks for the honour done to me in making me its Honorary Member.

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*The Rt. Hon'ble Sir Akbar Hydari, P.C., Kt., D.C.L., LL.D.

Knowledge of the fact that among your Honorary Members are many distinguished men makes me all the more conscious of the honour thus conferred.

I fully recall the opening of your Hyderabad Centre nearly three years ago and I am glad to say that it has not only been functioning effectively but functioning with enthusiasm too, which no doubt derives its strength as much from the support which you have been receiving from your Public Works Member, notably my Hon'ble colleague in the Council, Raja Dharam Karan, as from the interest evinced by all those engaged in the profession in this State.

You have rightly alluded to the role of an Engineer as a builder and although you have paid me the compliment of calling me a builder in that wider sense, it is a compliment which I must pass on, with the full consciousness of its being well-merited, to those of you who have in their own great or small way contributed to the building of modern Hyderabad. I must particularly mention the valuable services rendered to the State by the foremost of your Engineers, Ali Nawaz Jung Bahadur. He may recall the occasion, which I well remember, of a visit which I, a layman, paid in the company of two Engineers, himself and Mr. Lloyd Jones, over twenty years ago to the site where subsequently was constructed the second biggest dam in India which now holds the waters of the River Manjira and brings the blessings of plenty to a district once comparatively poor. That work is one of which Ali Nawaz Jung Bahadur and those who helped him in its execution may well be proud, and I ascribe to that visit the whole-hearted support which it was my privilege to give as Finance Member to the Nizamsagar Scheme.

I must express satisfaction at the fact that you have not been unconscious of the great progress being achieved, the great schemes being undertaken and completed, the gigantic resources being built up and the strides being taken of which you see manifestations in every walk of life in these great Dominions. It is, if I may say so, part of the training of an Engineer's mind that it is in general constructive and not destructive. In a world so keen to criticise without knowledge, to demolish without having the desire to build, it is a trait to be cherished and nurtured.

Let me add that these evidences of progress are due entirely to the inspiration and the help which we in the Government receive from His Exalted Highness. During the thirty

years of his rule, Hyderabad has changed beyond recognition and it is to him more than to any one else that we should ascribe the qualities of a great builder—even more than that, the qualities of a great architect, for there is underlying the great structure that he has built an equally great conception, that of achieving a united Hyderabad, enjoying the highest status and stature within the British Commonwealth of Nations.

Mr. R. K. NARIMAN, M.I.E., M. Inst.C.E. &c.

CHAIRMAN, BOMBAY CENTRE.

**Brother Engineers*:—I shall begin by thanking you for electing me your Chairman for the coming year.

Our Honorary Secretary told me that one of the duties of the Chairman is to address you. I do not like the task. But since it is a duty I shall try to fulfil it. I shall not address you after the manner of a professor, but merely talk to you about some subjects near to my heart. In the days of my youth, misled by arrogance, sometimes I would say with the poet:

منم گفت بفرای ایزدی
بهم شهریاری و هم موبدی

And since bodily ills react on the spirit, a priest must be a physician of a sort. So for a few minutes I shall act the physician priest, and begin by administering to you—

The pill

Digestive ! Tonic ! Antityphoid ? Well you shall tell. But remember, that though

"Outside, it is sergeant, Sir, salute salam"
Inside it is "brother, and it does no harm"

and at present we are 'inside', and I trust what I may say "do no harm". Perhaps some of you have attended a military

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* Presidential address delivered at the 20th Annual General Meeting, held in Bombay on the 17th November 1941.

R. K. NARIMAN Esq , M.I.E., M. Inst. C.E., etc
Chairman, Bombay Centre.
(1941-42)

funeral, have noted how the company proceeds to the cemetery with steps solemn, mournful and slow, while the pipes wail the dirge, the 'flower of the forest' etc. But when the coffin is in the grave, the volley fired, the 'Last Post' sounded, the return is in quick step to the enlivening tune of say the British Grenadiers, etc. So, as a beginning, I am going to speak of what others think of us. The enlivening part may come later. There are many who charge us—you and me—with that basest of vices, ingratitude. Ingratitude to whom? To our departed ancestors, they whose painfully, slowly acquired knowledge and experience, we inherited or was imparted to us, they by whose reflected glory, many of us shine. Wherein lies our ingratitude ? Year in and year out, we meet, eat, drink, talk, chaff—and never give a thought to those who have helped us to be what we are. Let us prove them wrong.

Rise Fellow-engineers and pay your homage to our distinguished predecessors. And may the spirits of our predecessors look down on us, think of us, bless us, and guide us to help mankind !! Nay, do not frown, if I pour out no libation—changed time makes this unsuitable. But look, in memory of you, my locks are shorn, even though I have not left them at your tomb—you are so many, scattered over the four corners of the world, some even beneath the ooze of the seven seas. Here is to the memory of our glorious dead.

"Ave atque Vale"!!

Part II

The draught or the mixture.

I thank you for the manner in which you swallowed the pill. I trust you will gulp down this draught with equal grace. Sweet ! Sour ! Bitter ! Soothing ! Irritant ? Well that will depend upon you—and your taste.

Proverbs are stated by some to be the crystallized essence of the experience of those who have gone before us. One of these proverbs is "I have been young and I am now old, but never have I seen the seed of the righteous begging its bread." May I request you to remember that in your dealings with our fellowmen? I am constrained to speak of this, because in the few short years that I have lived amongst you, I have heard—even in this room—of many acts, spoken with levity, as though they were so common as to be venal acts which a properly constituted society would look down upon, acts which an institution like ours ought to frown on and suppress. We

ought to feel that conniving at malpractices is almost as bad as perpetrating them. It should not be possible for us to hear with complacency—as some of us have heard in this hall—parties boasting of conniving at irregularities and encouraging acts illegal or against the ethics of our profession, merely because, such connivance helped them to achieve their aims. We should think more of the profession, and discourage practices derogatory to our profession. Think more of the greatness and nobility of our profession, more of service to humanity, and less of ourselves. We engineers are supposed to be ingenious, let us be frank and ingenuous also. For

Who are the happy, who are the free ?
You tell me and I will tell ye
Those who have lips that never lie
Truth in the face, truth in the eye
To all above, to all below
These are the happy, these are the free
And may it be so with you and me.

Fellow-engineers,

May I now speak about the subject which is occupying the attention of engineers in many countries, a subject on which I hold strong opinion. I refer to the position of the Engineer in society, amongst his fellow citizens. We engineers are accustomed to take pleasure and pride in our work. Some call us visionaries. We have visions, which we put down on paper and subsequently execute them in some solid material. Most of us unfortunately are not good mixers, and do not shine in society. Yes, I know that the girls go mad over our colleagues in the army, even though they speak of them as M M M mad, married or methodist. But then it is partly due to the glamour of the uniforms, partly to the emoluments they earn.

Consider our position in this city of Bombay which boasts of being the first city in India. The municipal code ranks practising engineers with licensed plumbers, and the legislature considers the engineers unfit to sit on the municipal board as corporators. And this in a city which looks to the engineer for the removal of slums, for maintaining her roads in a fit condition to ensure even flow of traffic, towards maintaining her water and sanitary services, without which the city would be decimated by disease, for keeping her mills and

factories moving so that she may produce material for our fighting forces, for maintaining her communications lest we starve, for ensuring quick and efficient loading and discharge of the vessels in her harbour, which bring her the wealth, of which she makes such a brave show.

Why is this ? Because, our education is defective. At college we learn the rudiments of our profession and neglect the fundamentals of our obligations as citizens. How many of us take any interest in subjects of common interest, social, civic, etc. Doctors, lawyers, politicians and others shout themselves hoarse on the flood-litted platform. They are before the public eye. The public appreciates them. Whereas no one thinks of the engineer who designed and built the hall, in which these thunder, brought the electric power which lights up the platform on which they stand. You feel you are neglected. And perhaps one of the reasons for your indifference to unprofessional practices to which I referred before, is an indifference born of this neglect. Engineers, this may not be. Arouse yourself, take more interest in civics, in the humanities ; work in your municipality, your district board, your council. Work in these and other public bodies, not for power, not out of arrogance and conceit, but in the spirit of service to humanity. And your fellow citizens will get to know you better, to appreciate you and your work, and will acknowledge that they cannot do without you.

And to that end you have to educate your youth. You have to impart culture to the young engineers equally with scientific and professional knowledge. So that they may develop wisdom, knowledge, science—things which make a state a state and not an ant heap. And we must try and assimilate the best of the old apprentice system ; for the master was responsible for making the apprentice not only a skilled workman, but also a good citizen. And while we must have skilled workers in industry, as in commerce, we must remember that the engineer is primarily a human being and he must more and more play his part as an intelligent, and well informed member of society. We must remember this important point, when considering his training. For I feel that our present system of education does not develop reasoning and imaginative faculties sufficiently and we tend to develop human gramophones. Our University and College curricula are defective. Our Institution is trying to modify and improve these. For example it is suggested that one or more platoons

of Indian Engineers (territorials) be raised from the students of our Engineering institutions, and these be attached to the U. T. C. The instruction and experience that they will gain in improvising methods and executing work with material available on the spot will be of great value to them in dealing with civil works also. Help the Institution and yourselves by suggesting modifications in the syllabus of studies and the methods of training the coming generation. And help the present generation by taking a more active and honorable part in civics and humanities. Let the citizens learn and feel that engineers are gentlemen even if they be visionary, that it is not derogatory to mix with that indifferent fellow the engineer—without whom the wheels of the boasted civilization, culture, progress would slow down and may even cease to move.

Engineers ! It has been suggested that I touch upon a question which is agitating politicians and industrialists at the present time *viz*. Industrialism. It is a subject about which I know next to nothing. But it is said that there is nothing new under the Sun ; and if you were to study past history, you may find that our forefathers had similar problems. I may be mistaken, but I have an idea that the "Pindaras" were a by-product of the break-up of the Mogul Kingdom—the disbanded soldiers preferred loot to honest hard work. We learnt our lesson and after the Sikh Wars we started large works of public utility which employed masses of demobilized Sepoys. Similarly, I believe one of the reasons for starting some of our great schemes in a hurry after the last Great War, was to find useful work for the demobilized. While we are at war, we have to produce not only to feed and clothe ourselves, but also those who are fighting for us. But when the fighting stops, our production—of which less is needed—is increased by the labours of the demobilized. Our industrialists have to steer a middle course. To see that production is at its highest during this period of stress, but that there is no distress in the aftermath. And what should be our policy? Should we engineers and scientists—for scientists are engineers if you but see them in the proper light—take a ten-year holiday, as is suggested by some, who blame us for our inventions and assert that wars and the horrors attendant thereon would not exist, if we stopped all inventions, scrapped machinery, and went back to the days of the city republics of Greece and the Panchyats of ancient India? I do not think we can endorse that policy of despair. As I have stated before, we engineers are proud of our inventions, our works and constructions. We are

not ashamed because we designed and built aeroplanes, submarines, or the wireless and other marvels of the modern age. We designed and built them for the happiness of humanity. We meant these and others to reduce drudgery and to give mankind more leisure—leisure to enjoy life and be grateful to the Creator for His blessings. We gave power to man to accomplish much with less expenditure of human labour. And we succeeded. A hundred years ago, boys of tender age worked sixty hours and more a week in mines—now they attend schools free of charge. Fifty years ago, a forty-eight hour week was the goal of the workman. Before the war, in several countries a forty hour week maintained the workman in decent comfort. And that was due to machinery, designed, constructed and maintained by engineers. Blame not the engineers, for the present state of affairs. They gave the world power. If mankind, in its mad lust for power, misuses this, and instead of utilizing it towards alleviating misery, turns it to destory the fruits of labour of their predecessors, we engineers are not to blame. Unless we be to blame as citizens, who neglected their duty and allowed passions to pass beyond bounds......passions which led to wars. What then is our duty towards industrialism?. Again I repeat, I know not how to answer. I feel like one groping in a dark room full of furniture......knocking down, and hurting himself against some piece of furniture, wherever he turns. Still, with considerable hesitation, I suggest that, we retreat......to strike with greater force. That we have machines......but not factory cities. We do not want our healthy peasantry, the backbone of the country, to come and crowd the slums of our congested factory cities. But remove your factories to the country. Give employment to our agriculturists near their homes during the non-agricultural season. Even now we are doing that in a small way. We have ginning and pressing factories in the outlying places, employing labour when it is not wanted for agriculture. We may have small presses, spinning and weaving factories, works for making paper and cardboard from corn or sugarcane stalk, etc. scattered all over the country. And we engineers can help by supplying cheap electrical power, designing and maintaining machinery for such factories which would employ comparatively few local men. The Punjab, U. P., Mysore have set the pace. But proud Bombay could not appreciate the power engineers gave her. It is only within the last year or two, I believe, that the Bombay hydro-electric works have been able to dispose of their available power.

And for the past seven years or so I had been advocating that this surplus power may be used in alkali, ammonia, carbide and similar works to be started on the creek near the Tata Power generating station. If Bombay wished, and politicians refrained from interfering with engineers......as they did during the construction of Tata Power Works......we can give cheap power to the country. Power which would improve the lot of the peasant, and give him more time to enjoy life.

Engineers! You boast of being the citizens of Bombay the beautiful (! ?)—a city created by your efforts—albeit thwarted by the short sighted policy of her city fathers. Look around. Are the dove-cots built along your famous Marine drive—where the inner rooms often require artificial light during day time—any credit to you? You shelter yourselves behind the usual excuse—Our clients wanted this, and we gave what they wanted. Engineers, that is not the spirit. It is our duty to explain to our clients what is best under the circumstances, and if they persist in ignoring your advice, it is for you to refuse to proceed with the job, rather than prostitute your talents by encouraging expenditure on undesirable constructions. Look at the new palatial buildings in the fort area. You design and construct them for light, air, ventilation ; but permit the owners to block up the windows and rent these as petty shops. The result ! The facade which you took so much trouble to design, the pride of the owner and of yourself, is hopelessly spoiled, the carefully thought-out light and ventilation facilities are rendered useless, the tenant has to resort to fans and lights even at mid-day, and the streets are obstructed by the encroachments of these shops on the public road, and the throng of customers standing in front of them. You say you are helpless. You have no power to enforce proper use of the structures you build. And after all, these alterations are permitted by the municipality. Engineers, do not deceive yourselves with such excuses. Yours is the responsibility to see that the facilities you provide for are not put to an ignoble use, for it reflects on you as designers and constructors. If you united, and boycotted owners who so misused your talents and used your rights as citizens to force the municipality to revise the building code and work it, so that such disgraceful scenes be not seen in this the first city in India, visited by thousands of overseas visitors, each with a vote in her/his own country, you would have done a lot towards removing this blot, and at the same time increasing the prestige of India and Indians amongst these foreigners.

Engineers ! Have you not felt the want of a decent public library on engineering subjects in this city ? Your University refuses to have engineering books. The other well-known libraries—even the Sassoon Mechanic Library—have but few works on engineering subjects. Is it not time that we bestirred ourselves and saw that this city had a decent library of engineering works, available to anyone wishing to consult it. Look round. Is this a library befitting our Institution ? Can we not improve it ? Our finances do not permit of buying all the books we would like to have. But we may make a beginning by asking Government ! and all quasi Government Services like the railways, docks, local board authorities, state administrations to send us copies of their publications. That will help us somewhat.

But if and when we do get these books, where are we to house them ? The capacity of our library-room is limited. As you see this room is already congested. We want more accommodation for our library and for our meetings. Our past chairman Mr. Daruvala started collecting funds towards a building of our own. You know the result. It appears that for the present we must postpone that idea. But something can be done, if we—the various bodies interested in engineering—unite, hire better accommodation, say an Engineer's hall and while allowing each contributing unit to have perfect liberty to manage its own affairs, arrange to have more space for our bookshelves, and our meetings—these to be open to members of all the contributing societies. I put forward this suggestion for what it may be worth.

Engineers ! We have lowered the coffin of ingratitude, ignorance and discontent into its grave. The last volley has been fired. The bugle has sounded the 'Last Post'. And you are eager to return home, to the sound of the rousing drum.

Tramp, tramp along the land we go
Splash, splash along the sea
The scourge is red, the heel drops fire
The flashing pebbles flee.

But you still feel the after effects of the dirge ? You still wish me to act the physician and soothe you with

The Salve

Well, let it be so.

Not many years ago, one of the popular cries was "Do not introduce your donna to your pal". I am not going to follow that advice. I want to introduce you to my Madonna !

Water

Yes water in its various aspects. I may not have time to allude to many aspects of water as it affects us engineers And I may not speak of water as it dilutes the syrup or the whisky that you gulp down to revive and refresh you. I may not refer to her seductions as she murmurs or thunders over a rapid or a fall. I may not speak of her allurements, when as a cloud she plays hide and seek with the gibbous moon—yourself watching the foamy crests of the wild white horses break over the strand, the distant view of the hills, now flood-lit, now in shadow.

I shall leave that and other aspects for some future occasions, and trust that when you have wooed this capricious, fickle, unpredictable water, and got to know her better, you will one day come and speak of her charms, with enthusiasm and without jealousy. For she is fair, she is just, in her own unpredictable manner and though wooed by many is partial to none. So, I shall speak of

Water and some of its aspects and problems connected therewith.

Man does not live by bread alone, said one. No, he requires cake and wine also said another. He may have added "and water too." For man can fast longer than he can do without water. And water is necessary not only as a drink, but also because it is required for the products of the earth—crops, fruits, birds, animals, fish—on which man lives.

Water reaches the earth in the form of rain, snow or sleet. It falls on the earth or the ocean or other large water surfaces. What falls on the ocean mixes with the water. Part of what falls on the ground is absorbed, flows underground and feeds rivers and streams. Part flows on the surface till it feeds rivers, lakes, etc. And since our whole system of agriculture and kindred industries *e.g.* dairying, fruit farming, sheep pasturing corn raising is mainly dependent upon water, we would like to know how much water, whether as rain or snow, we are likely to get in any particular year. If we knew that—we could arrange to use this expected available supply to the best advantage. For a long time it has been suspected that sunspots have an influence on rainfall. It would be interesting to know, how for the recent researches in cosmic ray support this suspected relation between rainfall and sunspots. We know

that rain and snow fall from the clouds and the clouds are formed of vapour *i.e.* of water evaporated from the seas and other surfaces of water and land or transpired by vegetation. Consequently if the clouds were stationary, one would expect a hot summer to be followed by heavy rain and snow fall. But the clouds travel with the winds and a fair portion of the rain and snow that falls on land is due to evaporation from the surface of the sea and lakes. Meteorologists have made rapid advances in recent decades. They believe that the frequency and number of sunspots visible at a time affect weather conditions. They observe the direction and velocity of winds, temperature, humidity and other factors, prepare charts and forecast weather conditions. But as yet these forecasts are only a short time in advance of the actual occurrence. The farmer and agriculturist is thankful for the day to day forecasts, as it helps him to decide hay making, harvest home, etc., but he would like to have more reliable forecasts for the season before it commence so that he may sow crops suitable to the amount of rainfall and know when floods are to be expected.

Though peninsular India is not affected by it, floods in the rivers of N. India, fed as they are by the melting snows in spring and summer are considerably affected by the snowfall in their mountain basins during the previous winter. In U.S.A. where floods play such havoc in the valleys that they are spending billions of dollars to obviate or reduce such flood hazard, the scientists are developing a technique of forecasting probable flood intensities by investigating the amount of snow in the mountains at the close of the previous winter. They regularly photograph the snows, investigate the snow cover and from these factors estimate the probable run off during spring and summer floods. Our irrigation system in N. India, also depends for their Kharif (or autumn crop) supplies on the water set free by the snow melting in the high Himalian Valleys. Our irrigation staff would be thankful for such early information about the amount of water likely to be set free by such melting of snow on mountain tops. They would in their turn arrange to distribute such supplies most equitably and advise the farmers about the most suitable crops to be sown for the probable amount of available water. The farmer is anxious to learn beforehand not only the total amount of rainfall for the season, but also would like to learn its distribution, month by month if not week by week. For a heavy downpour followed

by a long drought may give the same advantage as steady frequent showers, but the latter would suit the farmer much better than the former. Will meteorologists help us in this ?

Water for cultivation in the form of rainfall being so uncertain, man started to store up water and use this stored up water as required. Probably he first made use of water from the rivers or from pools and collected in natural depressions, to irrigate his crops. Perhaps he noticed that the level of water in these depressions and tanks got lower till they ran dry. His curiosity was roused. He wanted to know where this water went. He dug into the dry beds of these tanks and learnt the art of digging wells. Probably such was the origin of irrigation from rivers and wells. This was probably in prehistoric times. For the inscriptions, pictures on papyri, etc. from Egypt show that water was being raised from rivers for irrigating the land by "shadoofs" even during the early period of Egyptian history.

But raising water from a river is an arduous task. And it is more tiring to lift water from a fairly deep well. In these early days, the population probably was not all settled on the soil as agriculturists. They still had their floods and if the rains failed and rivers and wells ran dry, they would trek to more favourable areas, where they and their herds could get water. Probably they lost a large percentage of their flock in such treks. Even in recent times, such treks from drought stricken areas do take place, with consequent loss of herds although railways are harnessed to carry fodder to the drought stricken areas and the starving herds are transported to the more favoured pasture lands. Australia—Queensland in particular—is well-known for such devastating droughts. In India the drought of 1939-40 is reported to have reduced the sheep and cattle in Kathiawar, Rajputana, and S.E. Punjab by about 40 per cent—that despite importation of fodder and export of cattle. It is stated that in most cases the sheep and cattle die as much from want of drinking water as from want of fodder. And not only the cattle but also human beings who accompanied and tended them, must have suffered for want of water.

In the vast majority of cases, it is customary for the women to fetch the water required for their household. As pools began to dry and the water in the tanks to putrify, the women had to go further from their homes or encampments for water—and they did not like the extra labour. Perhaps they entreated, nagged and egged on their menfolk to find some means

of securing water with less trouble to themselves. Worried by the loss of their crops, harassed by the misery of their flock, nagged by their womenfolk, men thought of conserving water when it was available. They watched landslides. Noted how these held up the flow of streams and formed tanks and lakes. They copied nature. They built small dams across necks of streams or depressions. This was the beginning of storage tanks. These dams were built of gravel, sand, brushwood and earth—material nearest at hand. Such dams leaked badly, retained water for only a short time and the first freshet washed them away. Painful experience with these dams taught men that flowing water had power to brush away obstacles in its path *i.e.* it had potential energy. After generations of such misfortunes, one more advanced and observant than the others, thought of utilising this power. It is difficult to say how the potential energy of flowing water was first utilized. Probably the water wheel worked by the flowing water was one of such first appliances. We read of such being in use on the Euphrates and Tigris, the Nile, etc. in early historic times. The next step would be putting the power of falling water to use. Probably one day some one noticed water from a spring fall on a spring of willow. He noticed that the branch would bend under the impact, but that its elasticity would assert itself and it would spring back to its original position, it may be he substituted a plank for the branch, tied it to a tree and found that the plank would rise to its original position only if it was tied to the tree about its middle, so that the water fell on the shorter side of the plank, leaving the longer length at the other side to balance it. He thought over this and fitted the longer drier arm with a stone and watered this stone move up and down. And then some one conceived the idea of putting corn under the stone ; and so getting it husked. Then there was great rejoicing particularly amongst females who were thus relieved of the hard labour of pounding corn. You may still come across such primitive water hammers (if one may call them so) in use amongst some of the backward races, in primitive countries like Sumatra, Borneo, etc. Such may have been the beginning of the use of water power, which recent inventions and improvements have developed so much that each of the turbines at Bonniville Dam take 13,000 cusecs and work at 93 per cent efficiency. Would it be too much to ask Hydraulic, Mechanical and Electrical engineers and Physicists to contribute papers on the utilization of this power—the white coal—and occasionally hold a symposium, where these problems may be discussed jointly ?

Water is a fluid. It flows. It requires an envelope to keep it in place. In nature mother earth furnished this envelope. So we are interested in earth also, the more so as it influences not only the flow of water, but also its composition, owing to the salts contained in the earth. Water in its most common form occurs in lakes, rivers, tanks. Water reaches these either as surface or subterranean flow. In its course it gets contaminated. Flowing from its sources in the mountains with their steep slopes, it has considerable velocity, scoops up the earth and carries it along. Some of this earth (gravel and silt) it deposits at the foot of the hills. The deposits form a talus, the stream fans out and the comparatively clear water flows on in different channels. This water contains sand, silt, etc., the products of disintegration of rocks carried from mountains and salts dissolved by it in its progress over or through the ground. Silt and some salts are valued as fertilizers. But sand, gravel and several kinds of salts are a source of trouble to those who would use this water for agriculture or for raising stock. The floods spread sand and gravel over fertile areas and render these sterile. When carried on to their mouths by the rivers they form deltas, to the detriment of navigation and flood flows. The large number of derelict harbours *e.g.* Cheul, Sopara, Cambay, Broach mentioned by ancient historians and geographers of India but now neglected and derelict owing to silting of the channels leading up to them bear mute testimony to the havoc wrought by vast quantities of material brought down by the rivers and streams. Thus ours is a threefold task. To reduce the quantity of material disintegrated and washed down from the mountains, to arrange that the maximum of beneficial elements, the fertile silt, be spread over the greatest possible area and to arrange that desirable sand, gravel, etc., be deposited where it would cause the least trouble and become most useful.

To reduce the scouring of mountains, the method most generally urged is to cover it with vegetation—forests and scrub. The forest cover breaks the force of the raindrops, the scrub absorbs the rainwater and regulates the surface flow, thereby reducing the intensity of flow and its velocity and so prolonging but diminishing the flood volume. The scrub also protects the soil from erosion by the velocity of the water, reduced as it is by the resistance offered by the leaves and branches of trees and the protection offered by its blanketing effect. The men of the Forest Service would like to help conservation of

stream flow and reduce the deterioration of rivers and harbours, but they are handicapped by the opposition of vested interests, *viz.* the interests of the grazier, the charcoal burner, the casual cultivator and of others. The farmer requires to be trained to a proper system of ploughing and agriculture, so as to preserve the soil. We see many examples of incalculable damage done by forest fires, started by graziers. in the hope of grazing their flock on the tender shoots and grass that shoot up on such burnt out areas, after the rain. And for the temporary shifting cultivation 'China' as it is called in Ceylon, 'Thaungyi' in Burma but not uncommon in many hill and forest areas, indulged in by forest tribes, every year vast areas are burnt down. These burnt out areas enriched by the wood ashes, the forest tribes scratch with the plough, sow for three or four years and as the effect of the ashes and other plant food are washed away by the rains, with the surface soil and the soil becomes less productive, move off to burn down new areas. And the elements—the scorching heat of the sun, dew, frost torrential rain,. continue to wash away the soil .till it is again protected and covered with scrub and forest—a process requiring years. Or the thin layer of soil is washed away before the protecting vegetation gains a firm foot-hold and the bare rock is exposed to the sky.

And the removal of the vegetation cover in the hills is not the sole cause of the deterioration of our rivers, harbours, etc. A fair amount of water that flows from our rivers into the sea, has its origin in the rain falling on the plains. If these plains are denuded of trees as they often are for purposes of fuel or pasture during periods of scarcity or carelessly cultivated, so that the rich easily erodible soil is exposed to the full force of the rain and the fury of storms, or ploughed in the wrong direction, the surface cracked by burning summer heat allows the intense tropical showers to wash away productive top soil and form gullies, while the rich mulch is carried down the river to the sea to form sand bars. But it may be confessed that this denudation of the top soil is not confined solely to the action of water. When the protective vegetable cover is removed, the soil exposed to the action of the sun and frost cracks, turns to a powder and is blown off. The simoom of the Arabian desert, the loo and the dust storms of Rajputana and N. India,

the dust storms in the Mongolian desert and in the dust bowl of U.S.A. are due to the dust blown from disintegrated soil which had lost its protective cover. The dust may be deposited hundreds of miles away from the area from which it was lifted by the wind storms. And, all these unprotected waste desert areas are not solely due to the harshness of nature—many are due to the shortsightedness or ignorance or the lust of MAN for gold. A little more than hundred years ago, the Dust bowl of U.S.A. was a smiling prairie, supporting vast herds of cattle. Man came, with his insatiate greed, removed the trees and vegetation cover and ploughed up the land—often in the wrong direction. Down came the rain, water flowed along the furrows till these deepened and widened into gullies. The rain water carried this soil to the rivers, choked up their beds and caused floods and devastation along the riverside. Then followed summer. The soil cracked and turned into powder under the hot sun and the hot breezes blew away the rich top soil in clouds of dust. The river beds choked with this silt burdens, snags, etc. could not contain the flashy intensive floods within their banks. . The water overflowed the banks and spread over the fertile corn lands and manufacturing centres, creating havoc where it spread. Now the bureau of reclamation and other departments of U.S.A. are spending millions to undo the damage. One of these measures is the afforestation of all slopes steeper than 25 per cent.

Moritania, Lybia, Numidia, were considered to be the granaries of the Roman world. The density of population supported by these countries and their prosperity are attested by the magnificent ruins of ancient cities, aqueducts and other public works. These remained buried in sand for centuries and were only recently re-excavated. Since the departure of the Romans upto recent times these countries supported but a comparatively sparse semi-nomadic population. Whence this change ? The Romans encouraged silviculture. The mountains were clothed with forests. The denudation of hills and their descent down the streams was prevented by these forests. They conserved water, built reservoirs, aqueducts, canals, for domestic use and also for agriculture. Then came the pastoral Arabs with their goats and camels. They felled the forests. Their goats and livestock ate up the undergrowth. The streams came down not in a regulated flow but in spates and buried the valley under vast volumes of debris. The wind aided this destruction and both succeeded in filling

up the reservoir and covering the once fertile fields and teeming towns with sterile sand. The loss of storage capacity in reservoirs due to silt may be judged from the following:—

Locality of reservoir		Original storage capacity per sq. mile	Average annual capacity loss	Annual accumulation of silt in reservoir.
		Acre-feet	Acre-feet	Acre-feet
Darham N. C.	...	75·7	0·36	27·1
Santa Barbara, Cal.	...	67·3	4 82	325·3
Black Rock, N. Max.	...	31·6	3·83	121·0
Oakland, Cal.	...	404·8	0 43	174·0

(Note :—These figures are not strictly comparable, as they do not refer to the same period.)

In Mongolia, the Gobi has changed its boundaries. The storms blew its loose soil all over Central Asia. The great silk road of the ancients, along the Chinese lines, with the ruins of the sand buried cities of Khotan, the block houses alongside, attest to the density of population even in historic times, in this area, which had been converted into a desert by wind blown sand. The phenominal amount of silt carried down by the Yellow river has earned for it the nickname of "the Curse of China". During flood the water is almost liquid mud, the reported silt percentage being as high as 38 per cent. This silt percentage is expressed as weight of dried silt, and weight of water silt, to avoid absurd silt percentage as 80 per cent, 90 per cent.

Part of this silt burden is due to the denudation of the mountains, but in part it is due to the erosion of the rich loose soil in the upper reaches. Such erosion is accelerated by the removal of the vegetation and faulty methods of cultivation. The Yang tse Kiang is another river which drains a large area of loose plain and carries a large burden of soil and silt to the gulf of Chihli. Our own Sind-Rajputana desert was not always a desert. Tradition has it that elephants roamed in its forests. The ruins of cities, dotted over its surface testify to its population not so long ago. What has changed this once fertile area into a desert? Man and his ignorance. The senseless cutting down of vegetation in the mountains and along the foot hills, caused the mountain streams to bring down masses of

debris. This choked up the streams and caused them to fan out. The courses of the rivers were diverted, one can still trace some of these lost rivers of the Punjab and Rajputana. The Ghagar, which is now but a small river and ends in the sands of Bikaneer desert, was a mighty river only three or four hundred years ago, its floods were strong enough to prevent even an elephant from crossing it. The Hakra can be traced by the ruins of cities that used to flourish along its bank. The Saraswati and other rivers renowned in the Mahabharat and other ancient books, have dwindled to small streams and dry for more than eight months in the year. And the sub-soil water level in Rajputana has fallen so low that while a Rajput considers it disgraceful to sell milk—will readily present it to any stranger, sometimes he is not averse to begging for a drink of water, so difficult it is to procure it in that almost treeless waste. Ordinarily the Rajput employs a camel to pull up a small pot of water from the well—the weight of the long length and water is often too much for the strength of a man. And, worse, still the water of all the wells is not fit for human consumption—the percentage of the salts is too high. Something has been done during the past hundred years to push back desert which had been gaining on the cultivated areas during previous centuries. The canals have helped to restore some sort of vegetable cover and bind the soil so that the dust storms are not so frequent nor so intense as they used to be. The rivers are under better control and do not devastate the country as much or as often as they did before. The old stream beds and hollows are being dammed up to conserve the water supply. Old water reservoirs, with puddled sides and bottom and roofed over to reduce evaporation, have been repaired and restored. But much yet remains to be done. We want papers from Agricultural, Irrigation, Hydraulic and Forest Engineers on these subjects and discussions thereon.

I fear you are tired. You may not have the same regard for water as I have. So I will stop for the present. I may speak about some of its aspects on a future occasion, if you wish it.

You have noticed the sparkle of a well—cut stone. You see flashes of different tints and intensities. You shut your eyes for a moment, open them and look again and lo, there is a different shade. And so it is with water. It has various aspects, soothing like the dew or the gentle rain on a hot suffocating day, embarrassing like the downpour of a tropical shower, majestic as it tumbles in cascades down a precipitous

The Twentieth Annual Dinner of the Bombay Centre of The Institution of Engineers (India) held on 17th November. 1941 at the Taj Mahal Palace Hotel, Bombay.

mountain side, awful when seen as a tornado. But for all that, because I am unable to speak and express all that I feel about her, let me conclude with a misquotation.

"Much have I owed thee on life's rough way
Though secret woes the world hath never known
When on weary night dawned wearier day
And bitterer was the grief devoured alone
That I outlive such woes, enchantress, is thine own."

BOMBAY CENTRE.

ANNUAL DINNER.

The Twentieth Annual Dinner of the Bombay Centre was held on Monday, 17th November 1941 at the Taj Mahal Hotel, Bombay. Covers were laid for 122 persons, including 38 ladies. The Chief Guest was Sir Jehangir Boman Behram, Kt., B.A., LL.B., J.P. Other guests of the Centre were Dr. J. A. Collaco, L.M. & S., M.L.A., J.P., Mayor of Bombay and Mrs. Collaco ; Sir B. Rama Rau, Chairman of the Bombay Port Trust and Lady Rama Rau ; Mr. R. G. Higham, President of the Bombay Engineering Congress and Mrs. Higham ; Mr. D. W. Ditchburn, President of the Indian Institute of Architects ; Mr. Francis Low, Editor of the "Times of India" and Mrs. Low ; Syed Ali Raza, Chairman, Hyderabad Centre and Mr. Dildar Hussain, Member of Council from Hyderabad Centre.

The Dinner was held in the Air Conditioned Ball Room of the Hotel and the Hotel Orchestra and the Cabaret were in attendance.

Following has been the programme of papers meetings and visits at Local Centres.

BENGAL CENTRE.

10th December, 1940.	Discussion of the paper "Pozolan Soorkee and Jhama Slag Cements" by Mr. A. K Datta, Member.
23rd December, 1940.	A talk on "Modern Steelwork" by Mr. H. N. Sil, Associate Member.
24th January, 1941.	Discussion of the paper "The Education, Training and Functions of the Engineer" by Lt.-Col. A. G. Warren, Member.
27th February, 1941.	Discussion of the paper "Underground Supplies of Water in the Trap-Rock Zone in the Bombay Deccan and other allied tracts" by Rao Saheb N. S. Joshi, Member.
27th February, 1941.	Twentieth Annual General Meeting, Mr. N. V. Modak, the President, presided over the meeting which was attended by 60 Corporate Members, 1 Associate and 5 Students.
27th March, 1941.	General Discussion on A R.P. Shelters.
10th June, 1941.	Discussion of the paper "Approximate Method for calculating the Deflection of Beams" by Mr. D. S. Desai, Associate Member.
5th September, 1941.	General Meeting to announce the names suggested for membership of the Council to prepare voting papers and to appoint Scrutineers. 12 Corporate Members attended. Mr. L. P. Misra was in the Chair, Rai S. K. Guha Bahadur, Mr. B. N. Chaudhuri and Mr. J. Ganguly were elected Scrutineers.

VISITS.

7th January, 1941.	Visit to the Government of India Jute Research Laboratories at Moore's Avenue, Tollygunge, Calcutta.
8th April, 1941.	Visit to the New Customs House Construction, at Strand Road, Calcutta.
31st July, 1941.	Visit to the India Machinery Co., Ltd., Dassnagar, Howrah.
14th November, 1941.	Visit to Bombay Mutual Life Assurance Society Ltd., under construction, Calcutta.

BOMBAY CENTRE.

31st July, 1941.	General discussion on "Technical Education" by Members and Guests. (The discussion was opened by Mr. P. P. Adalja, M.I.E.)
13th August, 1941.	General discussion on "Road Deterioration in India" by Members and Guests. (The discussion was opened by Mr. T. R. S. Kynnersley, O.B.E., M.I.E.)
1st September, 1941.	Lecture on "Some Wonderful New Numbers" by Mr. D. R. Kaprekar, B.Sc., S.T.C.
11th September, 1941.	Lecture on "Acoustics" by Mr. J. P. Cassad, A.M.I.E.
18th September, 1941.	General meeting in connection with "Election of Members of Council" General meeting in connection with "Election of Members of Committee."
	General meeting in connection with "Contesting a Seat on the Senate of the University of Bombay."
25th September, 1941.	Lecture on "Engineer' by Mr A. A. K. Shaikh, A.M.I.E.
16th October, 1941.	Lecture on "Storm Water Drain at Dharavi. Its Deterioration and Reconditioning." by Mr. B. B. Patkar, A.M.I.E.
15th November, 1941.	"At Home" to the members of the Centre by the retiring Chairman, Mr. P. E. Colvala.
	20th Annual General Meeting and the Presidential address.
16th November, 1941.	Visit to the A.C.C. Building under construction (The management very kindly treated the members to light refreshment)
	"At Home" to the members of the Centre [illegible] wives by the members of the retiring Committee at Juhu.
17th November, 1941.	Visit to Shree Laxmi Silk Mills (The management very kindly treated the members to light refreshment)
	Annual Dinner, Sir Jehangir Boman Behram, Kt., B.A., LL.B., J.P. was the Principal Guest. 122 covers were laid, including 38 ladies.
18th November, 1941.	Visit to the Parle Products Manufacturing Co., (The management very kindly treated the members to light refreshment.)
	Lecture on "Welded Construction" by Mr. C. H. Shah, A.M.I.E.

HYDERABAD CENTRE.

16th August, 1941.	Discussion on Education, Training and Functions of the Engineer by Lt.-Col. A. G. Warren, M. I. E.
27th August, 1941.	Rainfall, Off-flow and Storage in Hyderabad State by Mr. L. Gangadhar, Sub-Engineer, P.W.D.

3rd September, 1941.	Manufacture of Aluminium, Chemical Fertilisers and Coal Products by Nawab Ashan Yar Jung Bahadur, C.E., A.I.E.E., M.I.E., Retd. C.E. & Secretary, P.W.D.
20th September, 1941.	Construction of Cement Concrete Road from Begumpet to Secunderabad by Mr. Sadiq Ali Khan, B.Sc., Asst. Engineer, P.W.D.
28th September, 1941.	Remodelling and Improvement to the City of Hyderabad by Mr. Meher Ali Fazil, L.C.E., Supdtg. Engineer, C.I.B.
26th October, 1941.	The Sun, Our Nearest Star by Rao Saheb T. P. Bhaskaran, M.A., M.R.A.S (London), F.N.I., Director, Nizamiah Observatory.
27th October, 1941.	Disintegration of Igneous Rocks due to the action of the roots of certain Rockloving Plants by Prof. A. R. Khan, A.R.C.S., B.Sc., (London), F.R.A.S., Retd., Principal, Osmani University College.

U. P. CENTRE.

The Twenty-first Annual General Meeting of the U.P. Centre was held at Meerut from November 21-24, 1941 with the following programme:—

21-11-41	11 A. M.	Annual General Meeting
,,	2-30 P.M.	Papers Meeting
,,	4-30 P.M.	Photograph
,,	5 P.M.	Tea Party
22-11-41	8-30 A.M. to 1-30 P.M.	Visit to Bhola and Salawa Power House, tube wells and canal works (55 Miles)
,,	8 P.M.	Dinner given by Mr. Sumer Chand, I.S.E., A.M.I.E., Executive Engineer, Irrigation, at his residence.
23-11-41	9 A.M.	Papers Meeting
,,	1 P.M.	Visit to Modinagar Sugar, Soap and Kotogem Works and Canning Factory.
,,	4-30 P.M.	Tea Party at Modinagar, Raizada G. M. Modi Proprietor was "At Home" to the members of the Institution.
,,	8. P.M.	Dinner given by Mr. H. C. Trivedi, M.I.E., Executive Engineer P.H.D., at his residence.
24-11-41	9. A.M.	Visits to Meerut College Hall and Military Works
,,	2 P.M.	Papers Meeting

MOHSIN ALI, Esq., I.S E., M.I.E ,
Chairman, U. P. Centre
(1941-1942).

S. I. CENTRE.

The Annual General Meeting of this Centre was held at Madras on the 6th December, 1941 with the following programme—

8 A.M.	Committee Meeting.
8-30 A.M.	Papers Meeting :—
	(1) A.R.P. Organisation by Mr. P. Venkataramanaraju.
	(2) Trivandrum-Nagercoil Road by Mr C. V. Nazareth.
10 A.M.	Inspection of the Napier Bridge Marina, near University Buildings.
4-30 P.M.	Photograph
5 P M.	Tea
5-30 P.M.	Annual General Meeting.
8-30 P.M.	Dinner (Bosoto Hotel).

BENGAL CENTRE.

Since the publication of the Catalogue, following books have been added to the Library.

Name.	Authors.
Cauvery Mettur System ...	(Souvenir of inauguration)
Rivers of the Bengal Delta ...	S C. Majumdar.
River Problems in Bengal ...	S. C. Majumdar
Regime Flow In Incoherent Alluvium ..	Gerald Lacey
Glossary of Technical and Vernacular Terms in Connection with Irrigation in India, together with Standard Notations	Central Board of Irrigation, India
Report, Aycut and Revenue Statements Accompanying the Revised Estimate of Mahboobnahair Extension Project, Medak District ...	C. C. Paul.
Note on The Purna Project ...	H.E.H. the Nizam's Government P.W.D.
Note on The Nizamsagar Project for the utilisation of the waters of The Manjra River ...	M. Ahmed Ali.

Name.		Authors.
A Study of Local and Civic Conditions in Mangalore Town	...	R. D. N. Simham.
History of the Rivers in the Gangetic Delta 1750-1918.	...	C. Addams Williams.
The Materials and Construction of Trunk and Distribution Pipe-Lines for Water Supply, using Metal Pipes ...	...	D. A. Howell.
Highways in the Punjab, Past and Future	...	W. S. Dorman.
A Study of Physical Quantities in Mechnical and and Electrical Engineering	...	John Wennerberg.
Laboratory Notes for Electrical Engineering Students ...	...	A. R. Nissar.
The Erosion of Steam Turbine Blades	...	F. W. Gardner
Indian Earths, Pottery Clays and Refractory Materials ...	...	W. H. Bates.
Regulation of Rivers without Embankments	...	F. A. Leete.
Bridge Engineering, 1933 ...	...	Dufour & Paul Schantz.
Rate Fixing and Estimating, 1941 ...	...	Joseph C. Freeman.
Refuses Destructors and Separation, 1938	...	A. W. Neal.
Foundations and Earth Pressures, 1939	...	C. Hyde Wollaston.
Locomotive Maintenance and Operation (Carriage and Wagon, Shop and Shed Practice) 1938	...	R. E. Brinkworth.
Punjab Rivers and Works, 2nd. Edn. 1912	...	E. S. Bellasis.
River Engineering Principles and Practice. 2nd. Edn. 1938 ...	...	F. Johnstone-Taylor.
Diesel and Other Internal Combustion Engines, 1938 ...	...	Howard E. Degler.
The Mechanics of Building Construction, 1934	...	Henry Adams.
Talking Pictures. 2nd. Edn. 1933	...	Bernard Brown.
Applied Chemistry for Engineers. 1940	...	Eric. S. Gyngell.
Structural Engineering. 4th Edn. 1938	...	Husband & Harby.
Solids and Fibrous Plastering. 1939	...	W. Verrall.
Industrial Electricity. 1939 ...	...	Nadon & Gelmine.
Street and Highway Problems. 1936	...	University of Oklahoma.

Name.	Authors.
Alternating Current Electrical Engineering 5th. Edn. 1937	Philip Kemp.
Hardness of Metals. 1936	F. C. Lea.
Electrical Contacts. 1940	G. Windred
Practical River and Canal Engineering, 1920 ..	R. C. Royal Minikin.
Water Supply Engineering. 3rd Edn. 1939 ...	Babbit & Doland.
The Rationalization and Conservation of the Timber Resources of The World. 1937 .	A Harold Unwin.
Steel Construction. 1939	Burt & Sandberg.
Elements of Machine Design. 3rd. Edn 1935 ...	Kimball & Barr.
The Strength of Materials. 3rd Edn. 1938 ...	John Case.
Handbook on Ball and Roller Bearings. 1920 ..	A. W. Macaulay.
Theory of Machines. 3rd Edn. 1938 ...	Toft & Kersey.
Mechanics of Particles and Rigid Bodies. 3rd. Edn. 1936	John Prescott.
Generation, Transmission and Utilization of Electrical Power. 2nd. Edn. 1941	A. T. Starr
Highway Spirals, Banking and Vertical Curves, 1937	H. Criswell.
Developing America's Waterways. 1936 ...	Marshall E. Dimock.
Practical Design for Drilling and Milling Tools. 1st Edn. 1938	C. W. Hinman.
The Elements of Railroad Engineering. 5th Edn. 1937	W. C. Raymond.
Theory and Practice of Alternating Currents. 3rd Edn. 1939	A. T. Dover.
Machine Design. 1939	Stanton E. Winston.
Pattern-Making for Engineers. 6th Edn. 1938 ...	Horner & Gates.
Model Laws for Planning Cities, Counties and States. 1935	Basset, Williams, Bettman & Whitten.
Bridges. 1929	Charles S. Whitney.
Air Raid Defence No. 1	Official Publication of the Air Raid Defence League.

Name.	Authors.
Air Raid Defence. No. 2	Official Publication of the Air Raid Defence League.
Manual for Officers Responsible for Air Raid Precaution Training	His Majesty's Stationery Office.
Your Home as an Air Raid Shelter • ...	Do.
Lighting During Black-Out Hours In Shipbuilding and Ship Repairing Yards	Do.
An Atlas of Gas Poisoning. 3rd. Edn. ...	Do.
The Detection and Identification of War Gases ...	Do.
Notes on The Construction, Maintenance and Replacement of Sandbag Revetments ...	Do.
Training of Air Raid Wardens	Do.
Memorandum on Aids to the Movement of Traffic to be Installed in Roads and Streets in the Absence of Street Lighting	Do.
Air Raid Precautions to be taken by Users of Ammonia	Ministry of Home Security.
Anti Gas Protection of Babies and Young Children	His Majesty's Stationery Office.
Wartime Lighting Rstrictions. (Lights carried by Road Vehicles)	His Majesty's Stationery Office.
The Choice and Adaption of Shelter in Houses ...	Do.
Questions and Answers on A. R. P. ...	Capt J. M. Hannay.
Pamphlet on Garden Trenches	Home Office A.R.P. Dept.
Specifications, etc., in regard to Permanent Lining of Trenches	His Majesty's Stationery Office.
Air Raid Precautions Training Bulletin No. 2 ...	His Majesty's Stationery Office.
The Air Raid Warden's Reference Book ...	N. S. Kiddel-Monroe.
The Nature of the Air Threat	The Air Raid Defence League.
Air Raid Precautions Services, Their Organisation, Duties and Equipment ...	The Concrete Association of India.
First Aid and Nursing for Gas Casualties 3rd. Edn.	His Majesty's Stationery Office.

Name	Authors.
Medical Treatment of Gas Casualties ...	His Majesty's Stationery Office.
Decontamination of Materials	Do.
Decontamination of Clothing, Including Oilskin Anti Gas Clothing and Equipment, from Blister Gases. 1st Edn.	Do.
Structural Defence. 1st Edn.	Do.
Bomb Resisting Shelters. 1st Edn. ...	Do
The Training and Work of First Aid Parties ...	Do
Camouflage of Large Installations	Do
Air Raid Precautions for Animals	Do.
Rescue Parties and Clearance of Debris ...	Home Office (A R.P. Dept.)
Organisation of Decontamination Service. 2nd. Edn.	Do.
Organisation of the Air Raid Wardens' Service. 2nd Edn.	Do.
Local Communications and Reporting of Air Raid Damages. 2nd Edn. ...	Do.
Notes on Training and Exercises ...	Do.
Provision of Air Raid Shelters in Basements ...	Home Office (A.R.P. Dept.)
Gas Detection and Identification Service ...	Do.
Protection of Windows in Commercial and Industrial Buildings	Do.
Inspection and Repair of Respirators and Oilskin Clothing	His Majesty's Stationery Office.
Domestic Surface Shelters	Do.
Care and Custody of Equipment ...	Do.
Emergency Protection in Factories ...	Do.
Professional Papers on Indian Engineering. Vol. I—VII 1863-70	Lt.-Col J. G. Medley.
Professional Papers on Indian Engineering. Vol. I—IV 1872-75	Major A. M. Lang.
Professional Papers on Indian Engineering 1st Series. 1874-5	Capt. Allan Cunningham.

Name	Authors.
Professional Papers on Indian Engineering. Vol. V —VII. 1876-78	Major A. M. Lang.
Professional Papers on Indian Engineering. Second Series. Nos. 33,39,43	Major A. M. Brandreth.
Professional Papers on Indian Engineering.. Third Series. No. 1,4, 7,10,14	Major A. M. Brandreth.
Index to the Professional Papers on Indian Engineering. 1st Series. Vol. I-VII. ... ... 2nd Series Vol. I—XI. ...	
The Mechanical Analysis of Tropical Soils ...	J. Charlton.
Design for Farm Buildings	G. S. Henderson.
A Preliminary Note on the Rice Crop in the United Provinces	R. L. Sethi.
Hydraulic Experiments at Roorkee ...	Capt. A. Cunningham.
Papers Refering to the Effect of Lighting on Buildings situated on Elevated Sites ...	Govt. of India P.W.D.
Roorkeé Hydraulic Experiments Vols. I, II, & III ...	Capt. A. Cunningham.
Notes on Testing Lighting Conductors ...	Capt. A. C. Painter.
Report of the Indian Irrigation Commission. 1901-3 Parts I, II & Maps	Government of India.
Collection of Reports and Correspondence on the River Training Operations at Okhla, Agra Canal.	
Notes on the Yield of Wells	Punjab P.W.D. Paper No. 63.
Notes on High Masonry Dams	G. L. Molesworth.
Reports on Experiments with Different Water lifts	W. J. Wilson.
A Few Notes on Sewage Disposal in England ...	H. B. Learoyd.
Plans Relating to Mass Dams and Dams of Arches Vol. III.	R. A. Ryves.
Notes on Mass Dams and Dams of Arches Vol. I ...	Do.
Diagrams Relating to Mass Dams and Dams of Arches. Vol. II	Do.
Engineering Conference Simla. Vols. I to V ...	Govt. of India, P.W.D.
Notes on Well- Sinking Work, Nadrai Aqueduct	W. B. Gordon.

BOMBAY CENTRE.

List of Books added to the Library during the Year 1940-41, List 2.

AR	15	A.R.P. Handbook	Concrete Association of India.	1940
EE	126	Electrical Tariffs for Domestic Supply and their effects upon the Development of Domestic Load	S. C. Bhattacharjee	1940
H	54	Effects of the Flow of Water through Permeable Foundations of Falls and Weirs, etc.	Ram Kishore	1940
MS, E	26	The Teaching of Statics	Prof. Harold Hotelling	1940
MS, E	27	Charcoal Gas Driven Lorries	B. K. Bose	1940
MS, G	43	52nd Annual Report of the Victoria Jubilee Technical Institute		1940
MS, G	44	Victoria Jubilee Technical Institute Magazine		1940
MS, G	45	The College of Engineering Magazine		1941
RF, G	29	Modern Bombay		1941
RF, G	30	Catalogue of Library Books, U. P. Centre		1939
RF, G	31	Catalogue of Library Books, Bengal Centre (2 copies)		1941
RR	21	Report of the Railway Board on Indian Railways for 1939-40, Vol. I		1941
ST	27	Scale of Charges for Consulting Structural Engineers	Institution of Structural Engineers	
ST	28	Structural Engineering-Education, Professional Training and Employment in Structural Engineering	do.	
ST	29	Draft Regulations Concerning the Design of Flat Slab Floors in Reinforced Concrete	do.	
ST	30	Report on Prevention of Dusting of Concrete Floor Surfaces	do.	
ST	31	Report on Retaining Walls	do.	

ST	32	Report on the Treatment of Welded Structures by the Metallic Arc Process	Institution of Structural Engineers.
ST	33	Specification for Concrete Pile-Driving	do.
ST	34	The use of High Alumina Cement in Structural Engineering	do.
ST	35	Report of Joint Committee on Loads on Highway Bridges	do.
ST	36	A Revised Code of Practice for the use of Structural Steel in Buildings	do.

Journals of the Institution of Civil Engineers.

BI-CE, J	9	Nos. 1-4	1939-40
BI-CE, J	10	5-8	1939-40
BI-CE, J	11	1-4	1940-41

Journals of the Institution of Electrical Engineers

BI-EE, J	36	Vol. No. 84, 85	1939
BI-EE, J	37	86, 87	1940

Journals & Proceedings of the Institution of Mechanical Engineers.

BI-ME, P	76	Vol. 143, Nos. 3, 4, 5	1940

Journals of the Institution of Sanitary Engineers.

BI-RS, J	24	Nos. 2, 4, 5	1940-41

Journal of the Institution of Engineers (India).

II-I, J	23	Vol. No. XXI—No. 2	1941

BOOKS RECEIVED

Following books have been received at the Headquarters for which the Council desire to make an acknowledgment and express their appreciations to the donors.

Problems in Hydraulics—D. L. Deshpande, A.M.I.E., and S. Raja Raman of the College of Engineering, Trivandrum.

Surge Phenomena—7 year's Research for the Central Electricity Board—

The British Electric & Allied Industries Research Association, London.

The Common Commercial Timbers of India and Their Uses—H. Trotters, I.F S.

Bengal Public Health Report for 1939, Govt. of Bengal, Public Health Dept.

Estatistica das Instalacoes Electricas em Portugal.

(Statistics of Electric Installations in Portugal.)—Portuguese Republic, Lisbon, Portugal.

Proceedings of the Bombay Engineering Congress Vol. No. 30—Mr. P. E. Golvala, Hony Secretary.

PERSONAL*

Following members of the Institution are on active War Services.

CAPT. K. L. JAIN, I.A.O.C., A.M.I.E.
CAPT. M.I.D. MUFTI, I.E. A.M.I.E.
CAPT. M. T. OSBORNE JONES, A.M.I.E.
MR. C. I. STABLER, M.I.E.
LT.-COL. E. E. V. TEMPERLEY, M.I.E.

Following members are actively associated in War Work

MR. P. R. AGARWAL, A.M.I.E.
NAWAB ASHAN YAR JUNG BAHADUR, M.I.E.
MR. E. J. HOGBEN, M.I.E.
MR. DILDAR HOSAIN, M.I.E.
MR. J. MITTER, STUD. I.E.
MR. K. R. VESUNA, STUD. I.E.

NAWAB ASHAN YAR JUNG BAHADUR, C.E. (Cooper's Hill), M.I.E. (Ind.). Retired Chief Engineer & Secretary, P.W D., has been appointed as Special Officer, War Supply Board, Hyderabad, and has been actively engaged on industrial expansion of Hyderabad.

MR. SYED ALI RAZA, B.A., B.Sc., (Hons.) M.I.E. (Ind.), A.M.I.C.E., Chief Engineer, N.S. Railway Construction, proceeded on leave on 16th October, 1941 preparatory to retirement.

MR. DILDAR HOSAIN, B.E., M.I.E. (Ind.), Assistant Chief Engineer, P.W.D., has been deputed to War Work and appointed as an A.R.P. Officer, Hyderabad State.

MR. J. M. L. BHATNAGAR, A.M.I.E. has been honoured with the title of "Rai Sahib".

DR. SHIV NARAYAN, M.I.E., has accepted an appointment on the staff of the Engineering College, Muslim University, Aligarh, U.P.

Mr. Raja Ram, M.I.E. through Mr. Anand Swarup Johri has presented his private Library of 850 books to the U.P. Centre. The Committee of that Centre have passed a vote of thanks and express their appreciations to the donor for this gift.

*Members are requested to send news of personal activities to the Technical Secretary for inclusion under this column.

NEW MEMBERS.

Since last publication the following names have been added to the membership Roll (corrected up to 10-11-1941) :—

MEMBERS.

No.	Name.	Address.
921.	Rickett, O. C., A.M.I E.E. ...	Executive Engineer, Mardan Divn., Electricity Dept., N.W.F.P., Mardan.
922.	Younus, S. M., B.A , B.Sc. (Hons.) Manch. ...	Executive Engineer, Osmania Buildings Project Divn., Jamai Osmania, Hyderabad (Deccan.)

ASSOCIATE MEMBERS.

No.	Name.	Address.
1497.	Vaidya, V. R., B.E. (Mech.) ...	Asst. Engineer, Eng. Dept., Messrs. Tata Hydro-Electric Power Supply Co., Fort, Bombay.
1498.	Choudhuri, S. R., B.Sc. (Eng.)	Power Superintendent, The Poona Electric Supply Co., Ltd., 2, Thumbe Park, Poona.
1499.	Batlivala, M. K., B.E. (Bom.) ...	30, Sleater Road, Grant Road, Bombay, 7.
1500.	Venkata Rao, P., B.A. (Hons) B.Sc. (Eng.)	C/o P. Vyasa Rao Esq., Kadri Road, Mangalore.
1501.	Sharma, B. R., B.Sc. (Eng.) ...	Chief Engineer, Swadeshi Bima Cotton Mills, Aligarh.
1502.	Patel, C. C., B.E. (Civil) ...	Chief Officer & Engineer, Navsari Municipality, Nishal Street, Navsari (Baroda State).
1503.	Domingo, T .B., B.E. (Civil) ...	43A, Inner Circle, Jamshedpur, *via* Tatanagar, B.N.R.
1504.	Apte, V. G., B.E. ...	District Engineer, 89, Snehalataganj, Indore City.
1505.	Subandh, M. N., B.E. (Civil) ...	Saraswati Sadan, 168A, Vincent Road, 2nd Floor, Dadar, Bombay.
1506.	Devadhar, V. S., B.Sc., B.E. (Civil) ...	11, Market Road, New Delhi.

ASSOCIATE MEMBERS (*Contd.*)

No.	Name.		Address.
1507.	Krishnamurty, D., B.Sc. (Eng.)	...	Asst. Engineer, The Surat Electricity Co., Ltd., Surat.
1508.	Hemnani, R. M., M.Sc., B.E. (Civil)	...	Thakurdwara Lane, Old Town Qr., Karachi.
1509.	Sahni, S. P., B.Sc. (Hons.) Lond.	...	Asst. Engineer, S.D.O. Tube Well, Chandausi, Dt. Moradabad.
1510.	Ratnam, V. S., B.Sc. (Eng.)	...	Western India Spg. & Wg. Mills, Kalachowki, Chinchpogli, Bombay.
1511.	Mohan, Yadava	...	Exec. Engineer, Unao Divn., Sarda Canal, Unao.
1512.	Kashyap, B. N.	...	Proprietor, Messrs. Kashyap Engineering Co., 21-A, Lawrence Road, Lahore.
1513.	Mitra, A. C., B.Sc., C.E.	...	Exec. Engineer, P.W.D., Irrigation Branch, 3, Canal Colony, Lucknow.
1514.	Gupta, S. L., M.A., B.Sc. (Hons.) Lond.	...	Municipal Engineer, Agra.
1515.	Mehta, J. K., B.E. (Civil)	...	Asst. Engineer, Nagpur Improvement Trust, Tulsi Nivas, Hump-Yard Road, Nagpur.
1516.	Balani, N .J., B.Sc. (Eng.)	...	Chief Engineer, The Tando Adam-Shahdadpur Electric Supply Co., Ltd., Tando Adam (Sind).
1517.	Desai, K. C., B.Sc. (Hons.) Eng. (Lond.), A.C.G.I.	...	Probationary Engineer, Chief Engineer's Office, Bombay Port Trust, Ballard Road, Fort, Bombay.
1518.	Venkaiah, G. S.	...	Mr. A. Rathnaiah's Garden, Kavadiguda, Secunderabad, Deccan.
1519.	Ghosh, Bidhu Bhusan, B.E., C.E.	...	Air Conditioning Engineer, Messrs. Refrigerators (India) Ltd., 13C, Russel Street, Calcutta.
1520.	Ali, Mir Najabat, B.E. (Civil)	...	Asst. Engineer, P.W.D., Nalgonda, P.O. Nakrekal (H.E.H. the Nizam's State).
1521.	Roy, K. P., B.E. (Civil)	...	C/o Superintending Engineer, Darjeeling.

STUDENTS.

No.	Name.		Address.
946.	Backer, P. A.	...	Near Town Hall, Tellichery.
947.	Agarwala, J. K.	...	Apprentice Engineer, Gun & Shell Factory, Cossipore, Calcutta.
948.	Bharucha, S. D.	...	Bachan Mansion, Tardeo Road, Bombay 7.

STUDENTS (*Contd.*)

No.	Name.	Address.
949.	Mitra, R.	... No. 4 (Karachi) Flight, Indian Air Force Volunteer Reserve, Drigh Road, Sind.
950.	Chattopadhyay, K .P.	... Student Engineer, B.N.Rly., Nainpur.
951.	Raj Kumar	... App. Mech. Engineer, 69, The Park, Ishapore, E.B.Rly.
952.	Malhotra, K. D.	... App. Engineer, Gun & Shell Factory, Cossipore, Calcutta.
953.	Prasad, V.	... App. Overseer, T.C.E.C., Roorkee, U.P.
954.	D'Costa, A. J.	... Casa de Major Palha, Patonga, Vasco da Gama, Goa.
955.	Das Gupta, M. K., B.Sc. (Eng.)	... C/o S. K. Das Gupta Esq., 44/2/2, Hazra Road, P.O. Ballygunj, Calcutta.
956.	Kelkar, K. A.	... 252/13, Sadashive Peth, Limayewadi, Poona 2.
957.	Krishna Kumar	... App. Overseer, Bhimgoda Headworks, Laljiwala, Hardwar.
958.	Sen, Sunil Kumar	... 63B, Townshend Road, Bhowanipur P.O., Calcutta.
959.	Tapaswi, M. N.	... 466, Congress Nagar, Nagpur, C.P.
960.	Dutta, Sudhamoy	... 20, Harcourt Lane, Howrah.
961.	Nandi, N. K.	... Room No. 51, Downing House, B.E. College, P.O. Botanic Garden, Dist. Howrah.
962.	Ranade, M. N.	... 167 F, Vincent Road, Bombay 14.
963.	Naegamvala, J.P., B.E. (Bom.)	... P.W.D. Chiplun, Dt. (Ratnagari.)
964.	Banerjee, Sudhiranjan	... 101, Sreeramdhang Road, Salkia, Howrah.
965.	Roy, Sitansu Kumar	... Downing House (East), B.E. College, P.O. Botanic Garden, Howrah.
966.	Roy, Parimal Kumar	... Downing House (Eastern-Block), B.E. College, P.O. Botanic Garden, Howrah.
967.	Chatterjee, A. N., B.Sc.	... C/o Babu Surendra Nath Chatterjee, Brahmo Samaj Road, Behala, 24 Prgs.
968.	Paul, Santosh Kumar	... 17, Ganesh Sircar Lane, Kidderpore, Calcutta.

ASSOCIATE.

No.	Name.	Address.
66.	Charat Ram, B.A.	... C/o The Jay Engineering Works, Calcutta.

The following candidates have not confirmed their election (corrected up to 10th November 1941).

MEMBERS.

Probhat Chandra Neogi	30-5-41.	Sarat Chandra Dam	19-9-41.
Meherali Fazil		M. L. Narasimiengar	

ASSOCIATE MEMBERS.

B. P. Sangal	26-9-40.	Syed Sarwar Hassan	25-8-41.
K. M. Kantawala	10-3-41.	Syed Ali Reza	
G. K. Chandiramani	30-5-41.	Sadiq Ali Khan	
M. K. Joshi		M. P. Raghavendra Rao	
D. R. Bhalerao		Bala Pershad	
P. F. Lakhani	17-6-41.	C. N. Dikshit	
B. S. Raju Iyer	12-7-41.	B. N. Chopra	
U. P. Mullick		Moti Ram	
N. R. Magal		P. J. Bhavanani	19-9-41.

STUDENTS.

M. S. Viswanathan	26-9-40.	Bhola Nath Vaish	12-7-41.
P. V. Govinda Rajan	31-1-41.	Pratap Singh Perti	
B. J. Mainkar	10-3-41.	S. Sivaraja Pillai	
		T. V. Venkataramani	
A. Venkateswarlu	25-4-41.	Ranjit Kumar Sikdar	
Phiroze D. Bharucha		A. Rajaratnam	
A. Sunder Raj	30-5-41.	Salil Kumar Roy	
Amiya Kumar Guha		Azim Uddin Ahmed	
Ranendra Nath Chakrabarty		Ajit Kumar Roy	
B. R. Rajagopalan		Md Mosharraf Ali	
K. Rajanraju		Mainul Islam	
Mohd. Aslam Sheikh		E. R. Shrof	25-8-41.
P. Mahadevan		Satinder Nath Gupta	
V. S. Mankikar	17-6-41.	H. P. Bharucha	
Prithvi Raj Puri		V. Krishnamurthi	
Lakshmi Chand		Naresh Chandra Das Gupta	19-9-41.
Ajoy Kumar Sircor		Asim Kumar Sarkar	
Dhirendra N. Goswami		Surat Singh	
Sunil Kumar Ghose		Md. Abdul Latif	
Kanu Priya Chowdhury		A. S. Somappa Sastry	
Maheswar P. Barman		Parimal Kumar Mukherjee	
Bijon Kumar Mitra		Susil Kumar Das Gupta	
Pranab Kumar Das			
Kanak Kumar Paul			

N. B. The date against a name indicates date of election.

List of applications under consideration as on 10th November, 1941 :—

(a) UNDER CONSIDERATION OF LOCAL CENTRES:—

BENGAL

A. Viswanadham	Shiva Prasad	R. N. Gandhi
D. B. Nagarker	Rabindra Chandra Das Gupta	Sachindra Nath Dutta
L. N. Tandon	Purnananda Bose	Subodh Chandra Das
Farid Uddin Khan	Ahmed Noor Mohammad	Rudra Mani Pradhan
Lekh Ram Mahajan	Mohammed Abdul Jalil	Sudhananda Chatterjee
Md. Nawab Ali	Lalit Mohan Mookerjee	Sailendra Prosad Roy
Md. Amzad Hossain Mollah	Mosleh Uddin Ahmed	R. H. Matthews
Prakash Chand Shingla		Sunil Chandra Biswas

BOMBAY.

T. K. Sharandhar	K. N. Tilloo	Woodrow Joseph da Gama
H. S. Murti	V. R. Rallapalli	K. R. Minocha
D. N. Gharpure	K. Nagaraju	Lieut. M. G. Raju
V. H. Kelkar	K. P. Mahalingam	N. N. Mehta.

HYDERABAD.

Mir Iqbal Ali Khan	Dr. S. P. Raju	A. G. Argade
S. K. Subba Rao		

MYSORE.

K. Ananthaswamy	B. M. Thippeswamy.	

NORTH-WEST INDIA.

K. S. Rafique	Syed Khadim Ali Shah	Sushil Kumar Sachdev
Trilochan Singh	Lachhman Dass Mullick	Ranbir Singh
K. R. Sharma	Ram Nath Kumar	Masaud Elahee Chohan
Sultan Mahmood Khan	Onkar Narain	M. Abdul Jamil
Yash Pal Kohli		

SOUTH INDIA.

A. Suryanarayana	K. A. Nanjundeswara Chetty	P. K. Aravamudhan
S. Subbaraju	T. R. Suryanarayanan	V. Sankaranarayanan
		Jivan Datt

UNITED PROVINCES.

Brijraj Bahadur	H. P. Srivastava	Sheoraj Singh
S. S. Gairola	N. Padmanabhan	S. Wali Raza
Devi Datt Semwal	R. C. Bhandari	B. B. Varma.
K. R. Ghatge		

(b) INCLUDED IN BALLOT LIST NO. 277

Chetan Das
A. H. Nanavaty
J. W. Keswani
V. B. Chiniwalla
R. B. Chitnis
H. Narayana Rao
H. V. Gopal Rao
R. Bhandari
D. K. Limaye
L. S. Dubhashi
Lekh Raj Grover
Om Prakash Sharma
S. A. Shakoor
Manohar Singh
S. V. Kulkarni
B. N. Godbole
S. K. Katrak
S. N Andhare
P. R Aramadhu
S. Varadaraja Sarma
P. Venkataramana Raju
H. G. Doshi.

(c) INCLUDED IN BALLOT LIST NO. 278.

Arun Kumar Das Gupta
Joy Deb Gupta
T. V. Sankarankutty Warier
D. R. Desai
Govind Das Parekh
S. S. Mazumdar
Nikhil Nath Chatterjee
Shanker Dass
Indra Mohan
Kawar Kishan Kapur
S. Venkataraman
Durga Prasad Misra
S. Sivaraman
Gopal Chandra Biswas
S. Bhaskaran

(d) INCLUDED IN BALLOT LIST NO. 279.

Mohd. Afzal Ali Khan
Md. Muzaffaruddin Ansari
P. D. Chowla
Jagir Singh
N. N. Reddy
Bhupendranath
Prafulla Kumar Sen
K. L. Sahni
L. N. Varma
S. B. Bhatnagar
B. V. Deshmukh
L. Ishar Das
K. V. Kupannah
Mohd. Jafar Ali
Lt-.Col. E. W. Slaughter
M. D. Gadgil
G. R. Deshpande
Balmukand Arora
Abdul Latif Olakh
Kailash Chandra Jain
Muzaffar Din Ahmad
Jogindra Pal Bajaj
Mejra-ud-Din
S. N. Handa
G. Das Suri
Gur Charn Singh
Prem Narain Sud
R. N. Vasudeva
Piara Singh Kler
Tilok Chandra Agarwal
Shiv Shanker
L. Gangadhar
P. V. Rajagopala Sastry
B. B. L. Kichlu

(e) INCLUDED IN BALLOT LIST NO. 280.

S. M. Irfanallah
S. B. Mathur
R. J. Dhumal
H. B. Neale
C. C. Chakravarti
Beni Madhav Singh
Paresh Chandra Dutt
M. C. Pande
V. M. Rane
Aniruddha Mishra
H. Yesonath
K. C. Pandya
M. V. Pantvaidya
N. D. Baria
Syed Zahurul Hasan
Om Prakash Sharma (No. 1)
P. N. Venkata Rao
Mata Prasad Misra
Om Prakash Sharma (No. 2)
S. R. Arulambalam
G. Sridhara Iyengar
J. L. Malhotra
K. S. Krishnan
D. Suryanarayana

(f) TO BE INCLUDED IN BALLOT LIST NO. 281.

R. Krishnaswami	A. Bhaskara Rao	Mohd. Haroon Al. Rahman
T. Satchidanandarao	R. K. Haridas	S. N. Wayakole
U. Satyanayana Raju	N. Sanyal	D. T. Sampat
T. S. Sankarasubban	N. Narasimha Murthy	

(g) BEING DEALT WITH AT THE HEAD OFFICE.

S. P. Sinha	P. P. Parikh	Satyaindar Kumar
J. H. Tarapore	Brahma Singh	S. S. Ambalia
V. V. Iyer	H. P. Mehndiratta	A. M. Pandya
Hari Singh	T. M. Pothon	Md. Abrurul Haq
P. S. Iyer	M. A. Alwar Iyengar	Subarnendu Gupta
M. P. Srivastava	G. L. Phadnis	

ADDRESSES WANTED.

A list of members whose mail has been returned by the Dead Letter Office is given below together with the addresses as filed in the Institution records. Any member knowing the present address of any of these members is requested to communicate with the Headquarters.

ASSOCIATE MEMBER.

M. R. Carr-Hall ... Asst. Engineer, B.N.Rly., Chauliganj, P.O. Cuttack, (Orissa).

STUDENT.

B. S. Chitale .. Engineer-Overseer, Malaria Field Station, Pattukkottai, Tanjore.

OBITUARY

The Council record with deep regret the death of the following members of the Institution.

A. C. Banerjee, M.I.E. (Member, Examination Committee and Education Sub-Committee).

A. W. H. Mathews, M.I.E.

J. P. Trivedi, A.M.I.E.

BRITISH STANDARDS INSTITUTION.

The undermentioned draft Specifications, have been forwarded by the British Standards Institution for comments.

C.F. (ME) 7844	Draft Specification for Tolerances for Plain Limit Gauges.
C.F. (RUC) 7738.	Revised Draft B.S. Specification for Rubber Rings for Sealing Domestic Preserving Jars for Fruits and Vegetables.
C.F. (CM) 7821.	Revised Draft B.S. Specification for Motion Picture Films.
C.F. (NF) 8060.	Draft B.S. Specification for High Purity Zinc : Zinc Alloys for Die Casting, Parts 1 & 2: Sampling and Analysis of High Purity Zinc and Zinc Die Casting Parts 1, 2 & 3.
C.F. (TIB) 7956.	2nd Draft B.S. for the Use of Timber in Building Construction.
C.F. (ME) 7961.	Draft War Emergency B.S.S. for Clockwork Mechanisms.
C.F. (WE) 8214.	Draft B.S.S. for the Welding of Copper.
C.F. (N(F) 8166.	Draft B.S.S. for Raw Copper.
C.F. (EL) 8192.	Proposed revision of B.S.S 156-1936—Enamelled High Conductivity Annealed Copper wire.
C. .F. (C) 8126.	Draft B.S. War Emergency Specification for Camouflage Paints.
C.F. (CEB) 7994.	Draft B. S. War Emergency Specification for Concrete Sleepers.
C.F. (B) 8008.	Draft Code of Practice for the Provision of Services in Buildings.

Copies of all British Standards Specifications may be obtained from :

Messrs. Thacker & Co., Ltd.,
P.O. Box No. 190, Bombay.

Messrs. Thacker Spink & Co., (1933) Ltd.,
3, Esplanade East, Calcutta.

Messrs. Higginbothams,
P.O. Box No. 311, Madras.

INDEX TO JOURNAL.

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